Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JULY 1959

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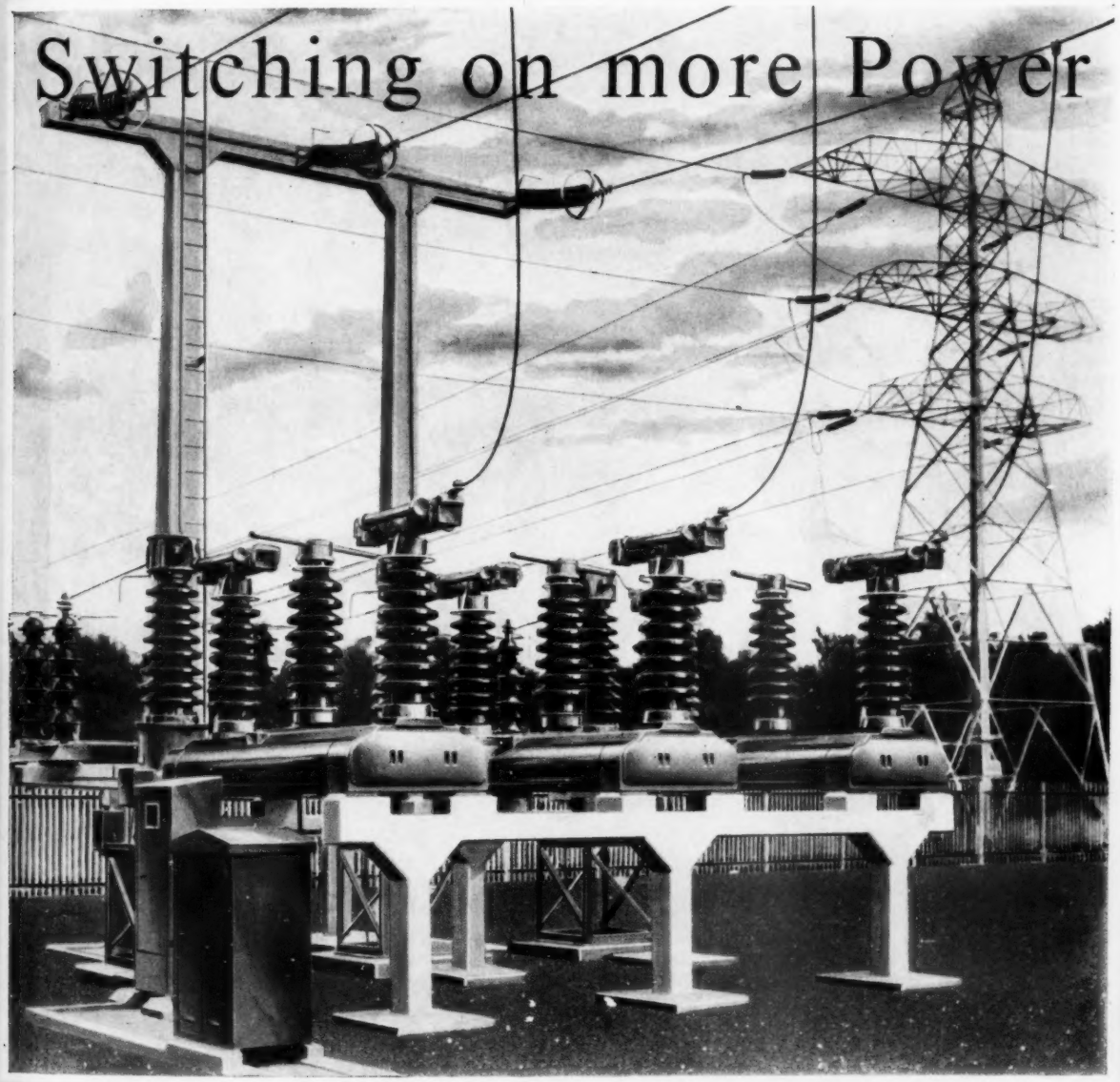


The photograph shows a Metrovick 132 kV., 3,500 MVA., Type GA6W4 Air-Blast Circuit Breaker installed in a British substation

This type of breaker is in extensive use on the British grid system, and has been selected to control the output of Scotland's first Nuclear Power Station at Hunterston. Overseas, 132kV., 5000-MVA., Type GA6W4 breakers will be installed in seven new sub-stations in the Greater Buenos Aires area of Argentina.

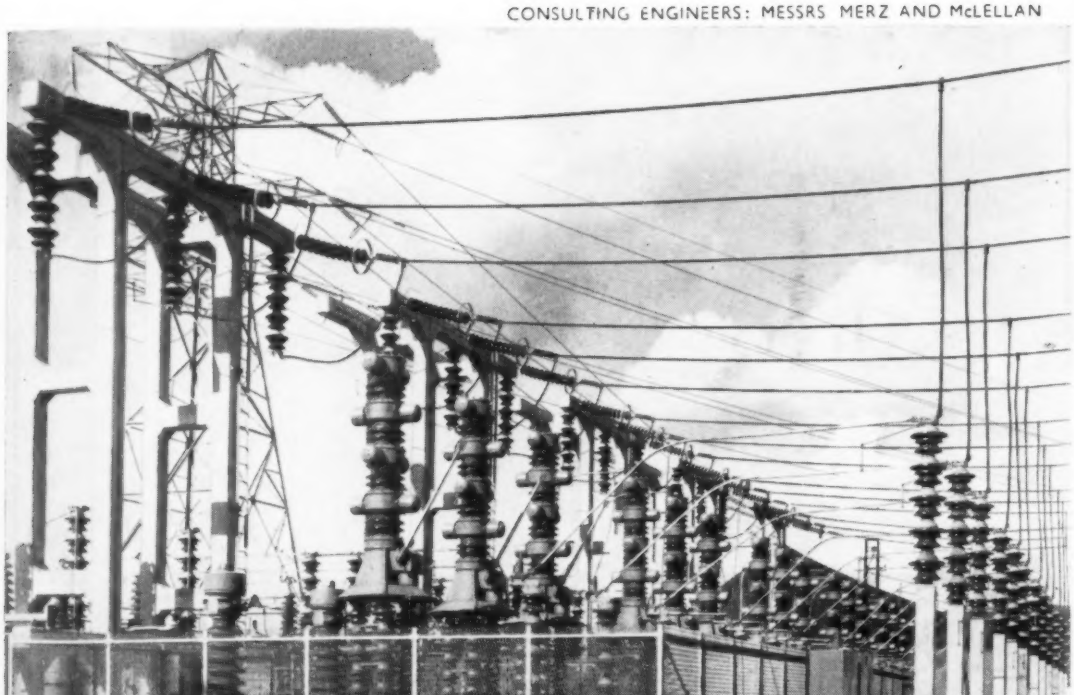
METROPOLITAN-VICKERS
ELECTRICAL CO. LTD · TRAFFORD PARK · MANCHESTER 17

Switchgear at Stella

The entire output of 540 MW
from the two power-stations
at Stella, near Newcastle upon Tyne
is controlled by Reyrolle
132-kV and 275-kV air-blast
circuit-breakers.

Reyrolle also supplied
the 415-volt and 3.3-kV
air-break switchgear for
the station auxiliaries.

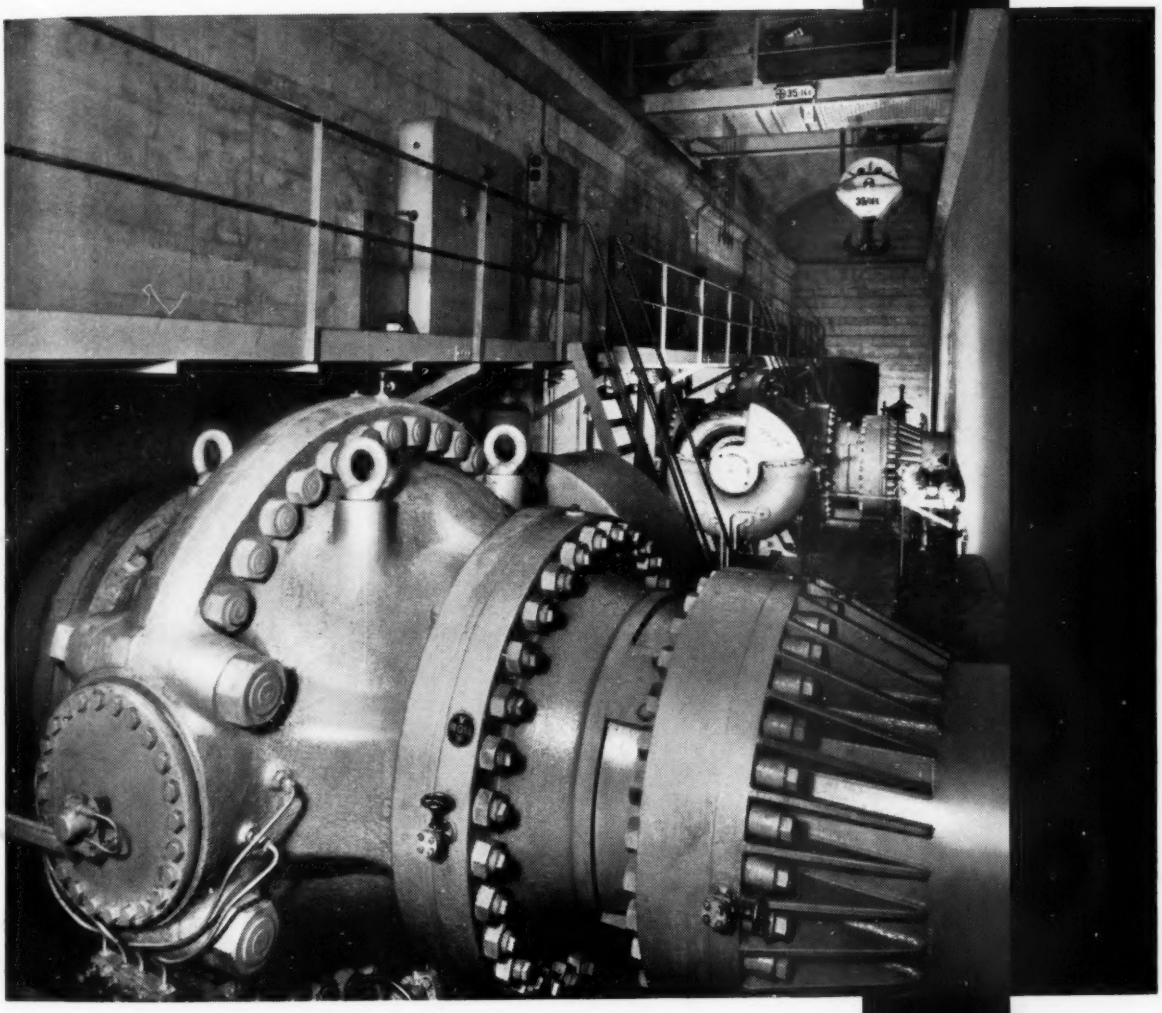
CONSULTING ENGINEERS: MESSRS MERZ AND McLELLAN



A. REYROLLE & COMPANY LIMITED HEBBURN, COUNTY DURHAM, ENGLAND

Photography by courtesy of the C.E.A., North-Eastern Division

Equipment for Hydro-Electric Power Stations



Valve chamber with rotary slide sphériques valves as turbine shut-off device in a swiss power station

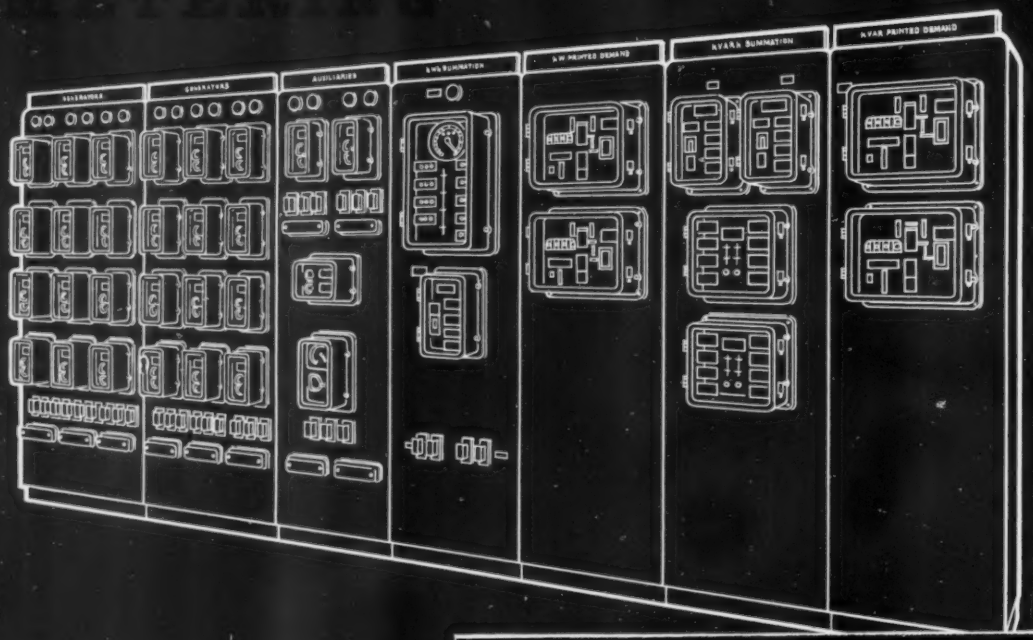
DE ROLL

Louis de Roll, Ironworks Ltd.,
Works at Gerlafingen, Klus,
Choindez, Rondez,
Olten, Berne (Switzerland)

Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work.

76

SUMMATION METERING

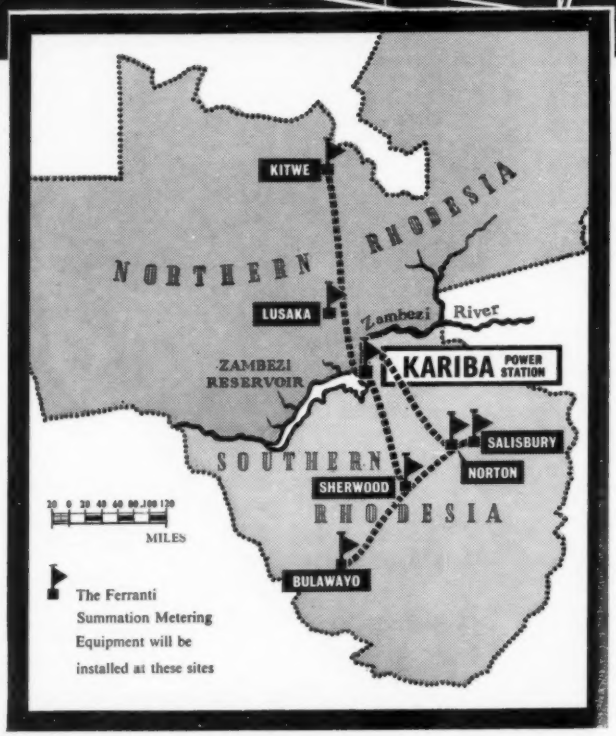


for the KARIBA HYDRO-ELECTRIC SCHEME

For the Kariba Hydro-Electric Scheme, Ferranti Ltd. have received an order for Summation Metering Equipment comprising: Precision grade integrating meters, Electro-mechanical summators, Printometer Demand Recorders and Suites of metering cubicles.

These equipments will be used to meter six 100 MW generator sets at Kariba Power Station and also the supplies to the Transforming Stations at Kitwe, Norton, Salisbury, Lusaka, Sherwood and Bulawayo.

The Mechanical and Electrical Consulting Engineers for the Kariba project are Messrs. Merz & McLellan.



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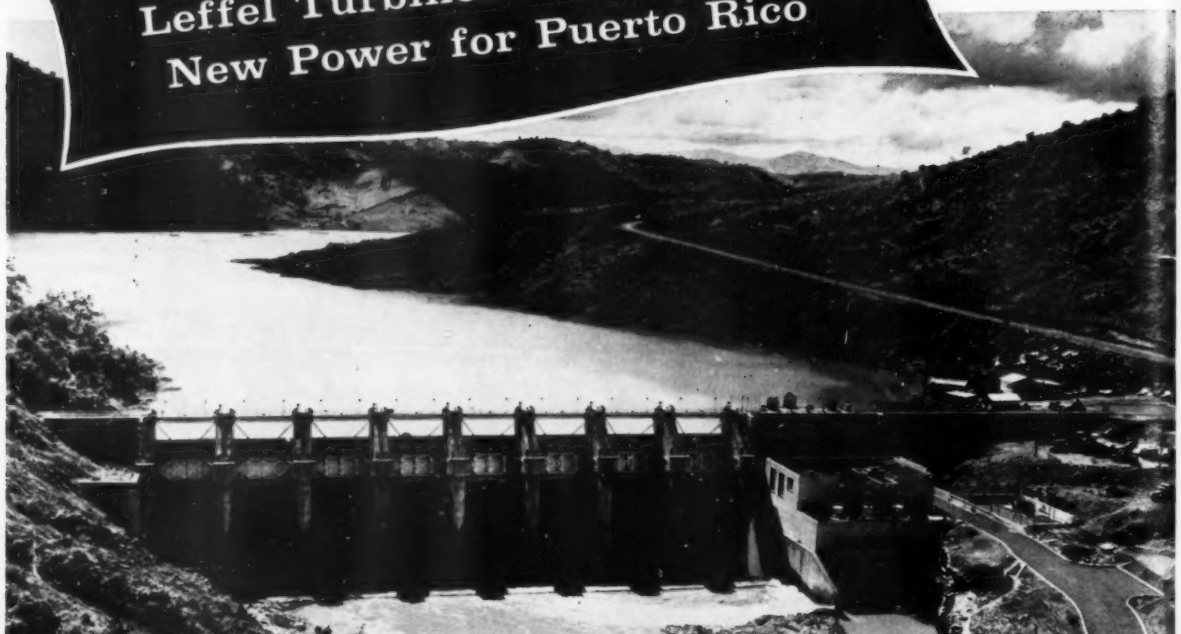
Leffel Turbines Help Provide New Power for Puerto Rico



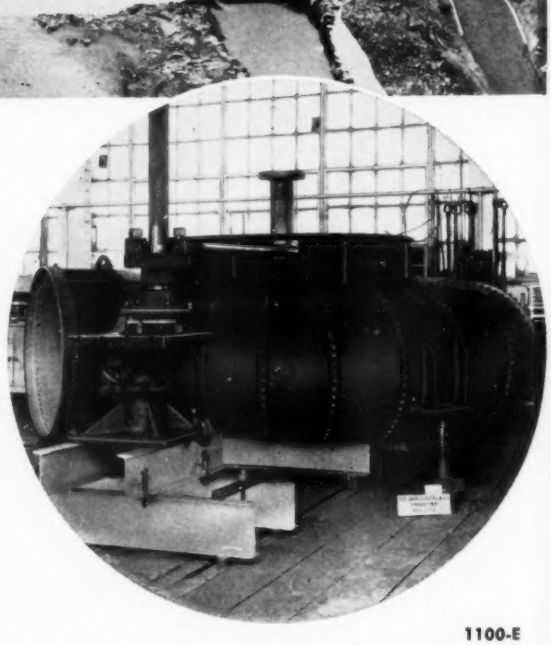
Rio Grande De Loiza Dam, a project of the Puerto Rico Aqueduct and Sewer Authority

At the new power plant at the Rio Grande De Loiza Dam, dependable Leffel turbines drive the generating units. Located at Trujillo Alto in San Juan's metropolitan zone, this project was constructed for adequate public water supply and hydroelectric power generation. It includes, in addition to the dam and hydroelectric plant, a filter plant and an extensive sanitation system.

Each of the three Leffel turbines in this station is rated to develop 1550 HP under 68 foot net head, speed 327 RPM. The view above shows the completed Rio Grande De Loiza Dam and hydroelectric plant. The view at the right shows one of the three plate steel spiral case turbine units being completed on the assembly floor of the factory.

Leffel turbines are dependably and efficiently harnessing water power all over the world as they are in Puerto Rico. Leffel designs and builds equipment for maximum reliability and efficiency — Leffel turbines last longer and do a better job because they're heavier and more rugged.

Leffel has been producing hydraulic equipment of the finest caliber since 1862. Before you plan your next turbine installation, whether it's completely new or the rehabilitation or expansion of present facilities write for the complete story. Our experienced engineers are ready to put their "know how" at your disposal . . . no obligation.



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Company_____

Street_____ City_____ State_____

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for fully mechanised and economic drifting and tunnelling.

SMG SALZGITTER

Short loading time ensured

— by the high loading capacity of the HL 400
— by continuous loading system
— by avoiding loss of time generally required for exchanging stone cars

Thereby:

more pulls per day, more advance in yards per day, reduced time for finishing project thereby lower overall costs.

No recesses in tunnel required for exchange of cars

Thereby:

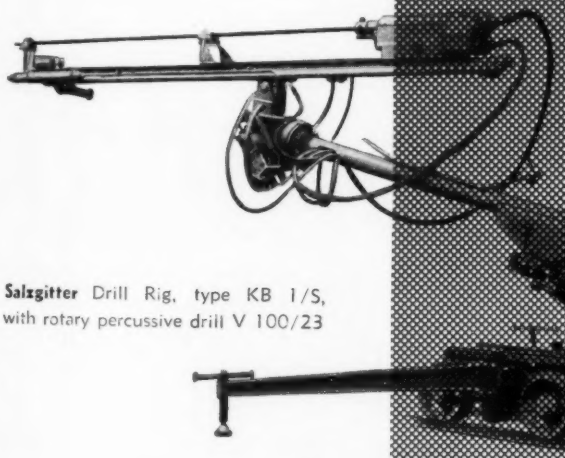
saving of costs for construction and support.

Saving of labour if Salzgitter Drill Rigs are also used

Thereby:

considerably reduced costs for wages per cu. yd. of tunnelled solid rock and saving of costs for labour and maintenance.

The economic advantages of the bunker train will be fully utilised in small tunnel sections (up to 14 sq. yards) in adjusting the length of pull to the loading capacity of the train.



Salzgitter Drill Rig, type KB 1/S, with rotary percussive drill V 100/23

The use of Salzgitter machines enables contractors to be highly competitive.

Salzgitter Loader, type HL 400, 14 cu. ft. bucket capacity

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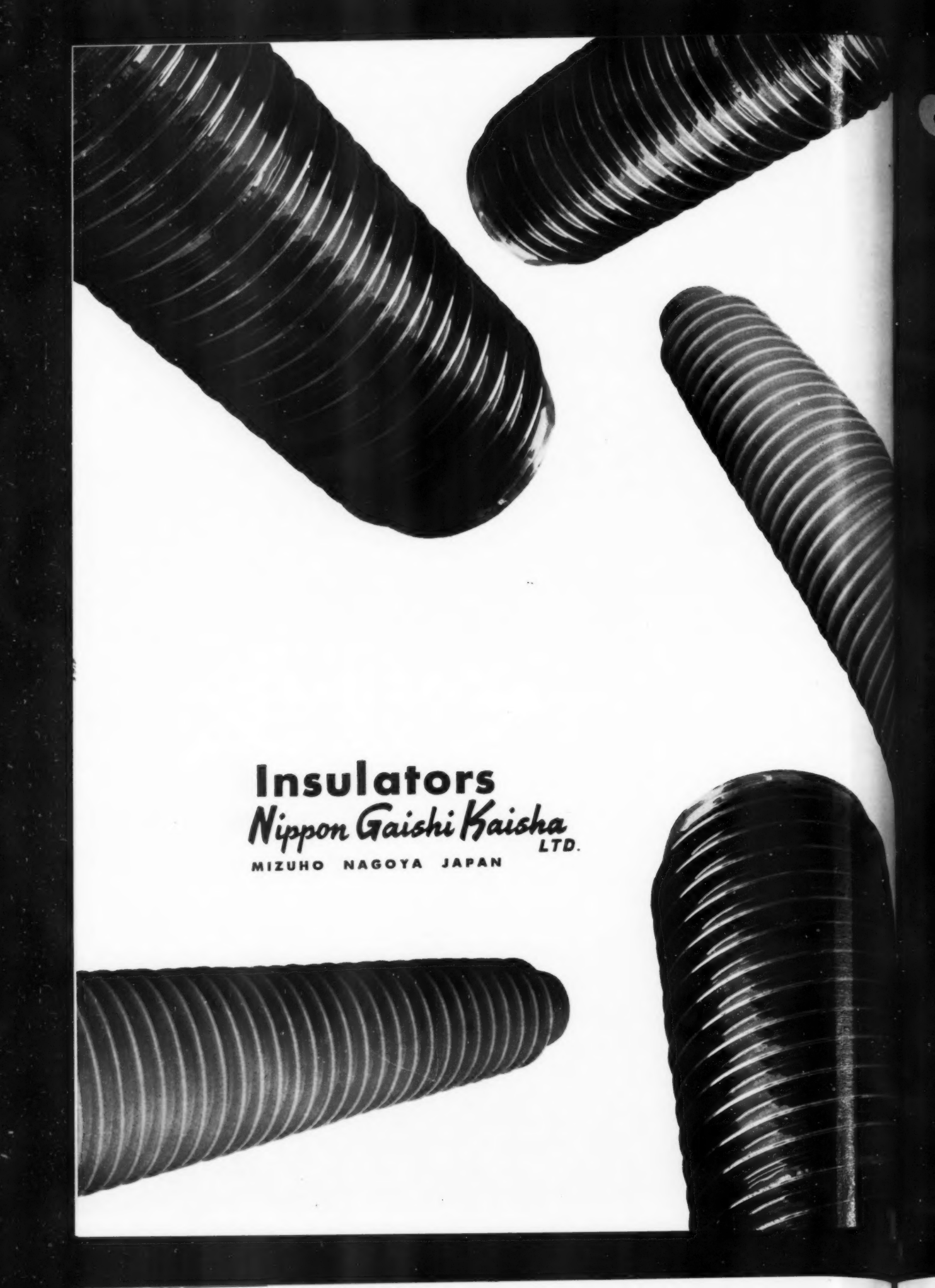
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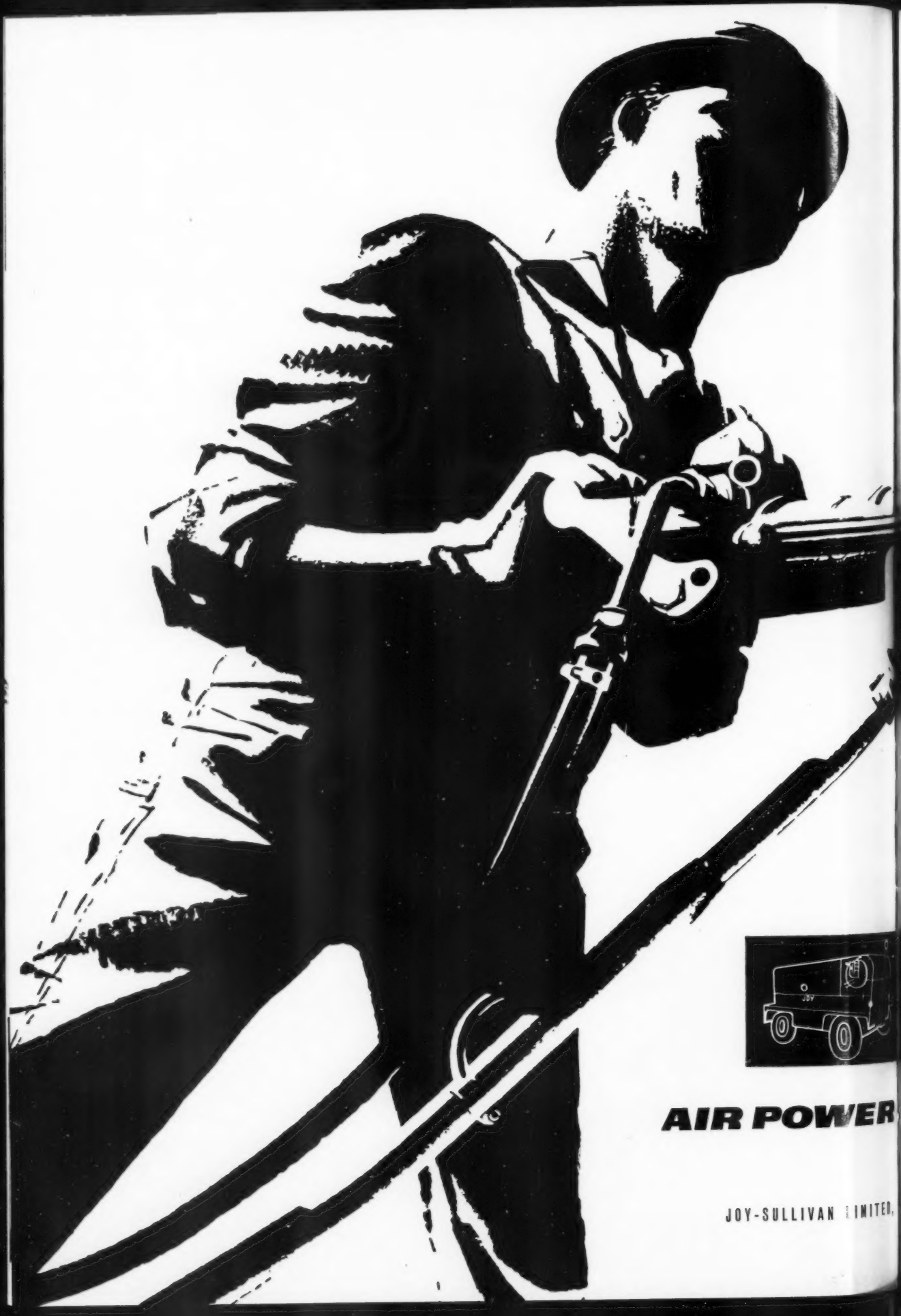
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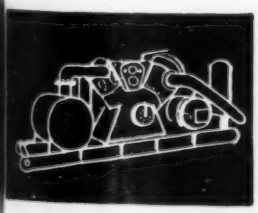

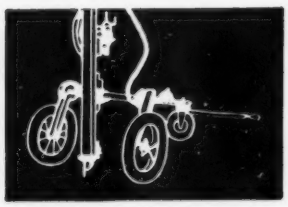

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JOY-SULLIVAN LTD
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AIR POWER DIVISION, 7 HARLEY STREET, LONDON, W.1. TELEPHONE: LANGHAM 7711

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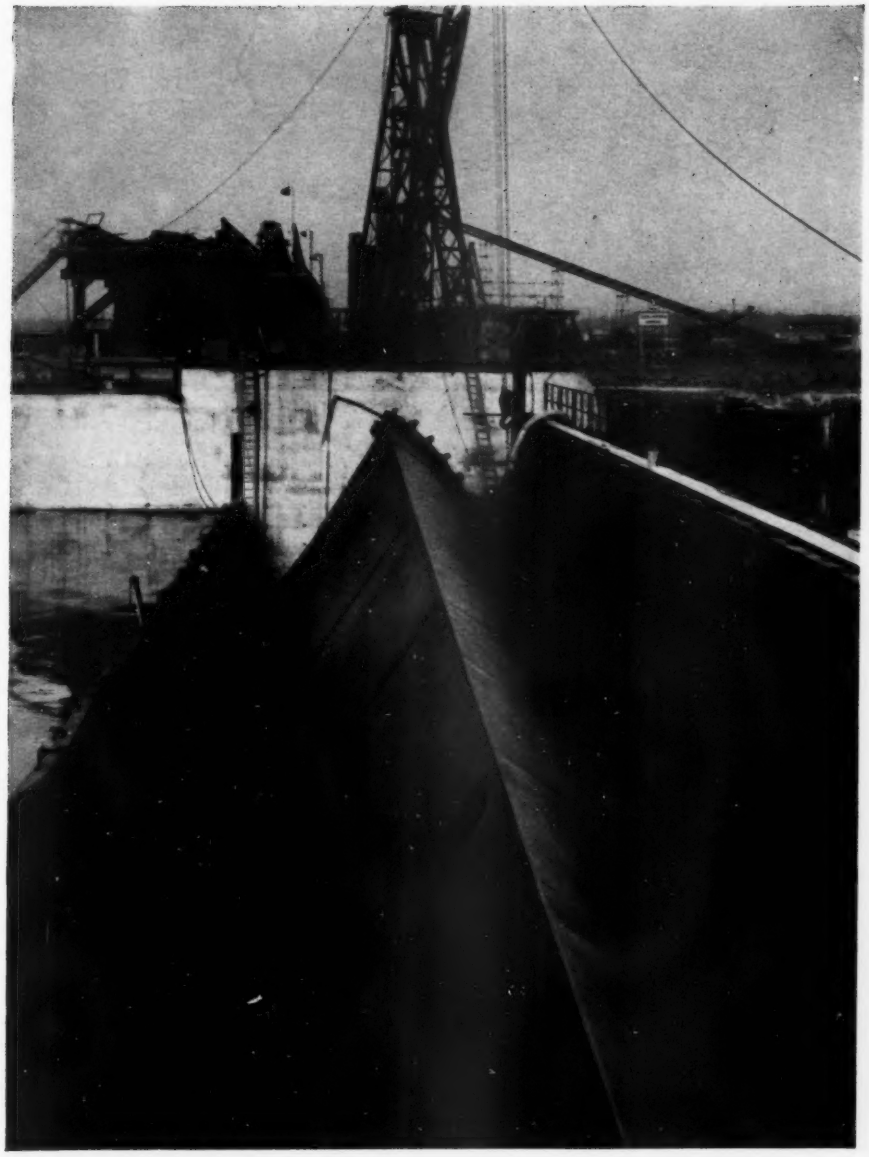

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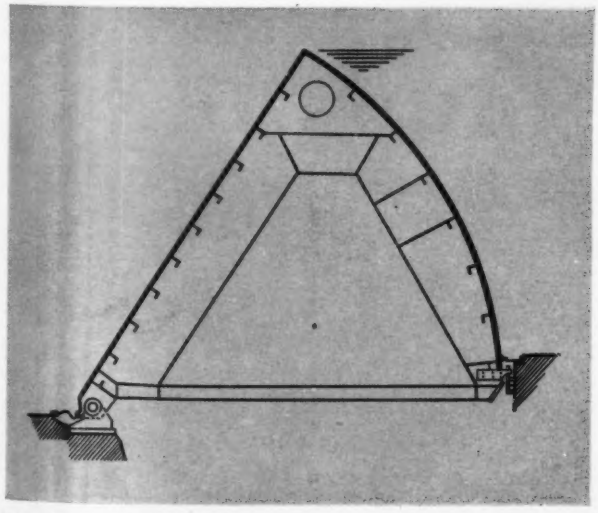

HYDRAULIC STRUCTURES

Sector weir of 50 m clear width and 4.55 m water head in the River Elbe at Geesthacht near Hamburg. Illustration shows the gate in course of erection. Sector weirs are hydraulically operated submersible gates moved by regulation of the water enclosed in the sector chamber. As opposed to drum gates, they are particularly appropriate for weir plants in rivers where comparatively slight variation in the water level occurs.

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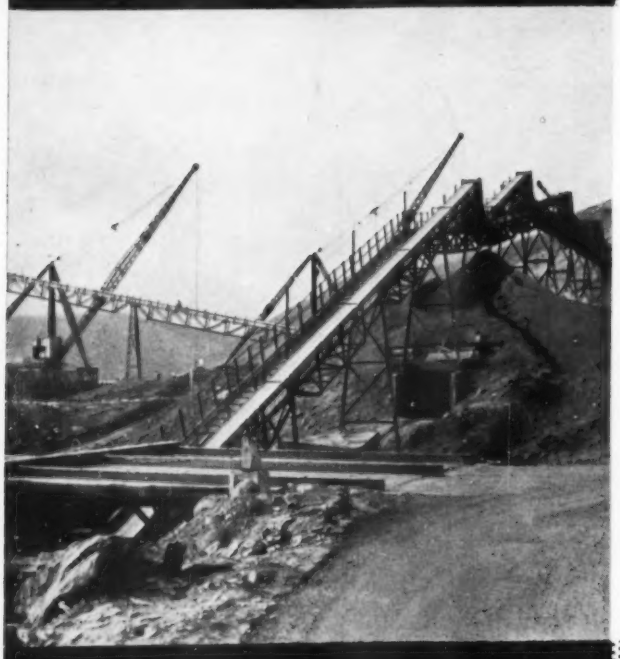

BUILDING FOR POWER

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.

They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

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Telegrams: Huwood Stock, London. Telephone: Monarch 3273 (8 lines).

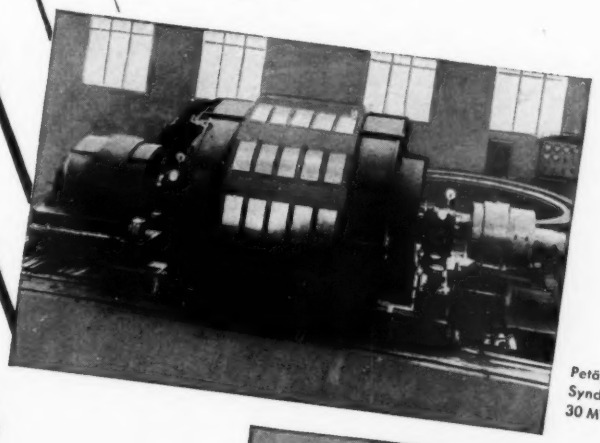
AEG

SYNCHRONOUS CONDENSERS

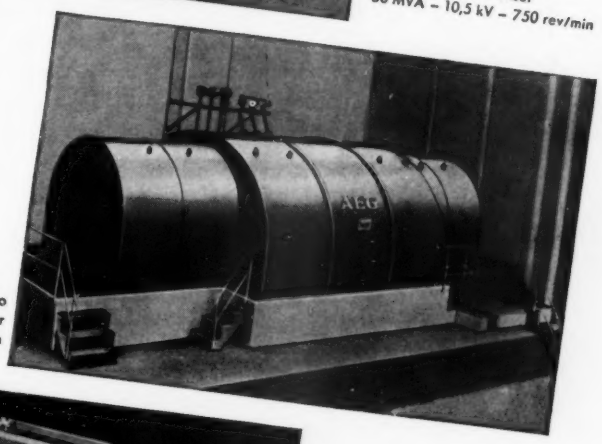
Economical operation of large grids and other distribution systems call for a compensation of the reactive component, i.e., improvement of the power factor.

Large synchronous condensers will best suit the purpose also under conditions of heavy line voltage fluctuations.

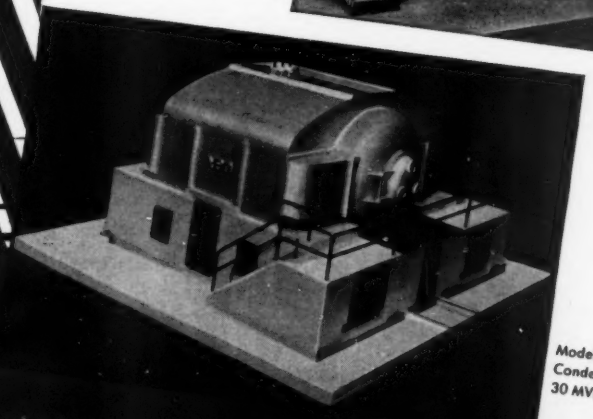
The AEG manufacturing programme covers all sizes of synchronous condensers for supply systems as well as for industrial application.



Petäjevesi, Finland
Synchronous Condenser
30 MVA – 10,5 kV – 750 rev/min



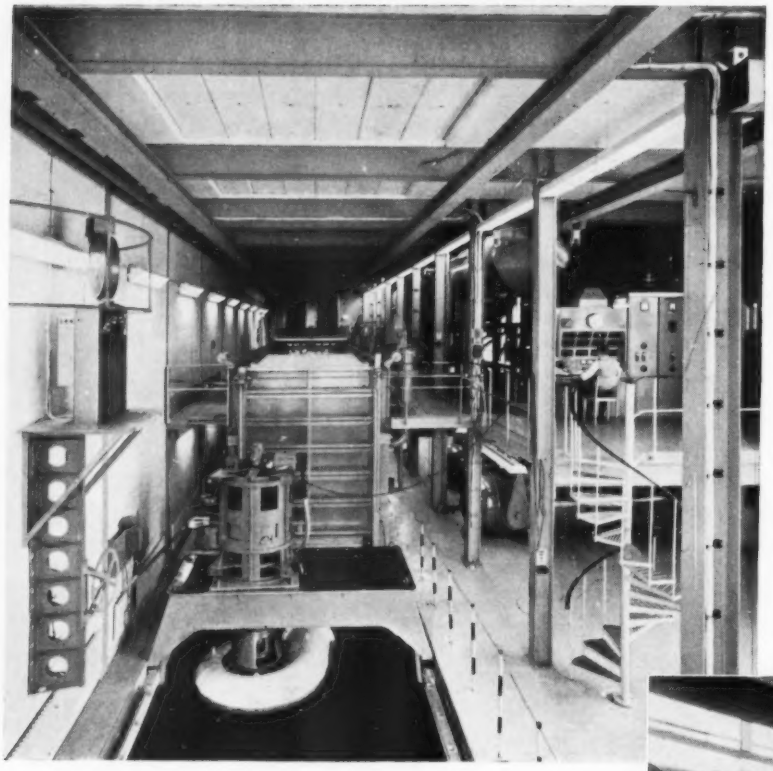
Norsk Hydro
Synchronous Condenser
36 MVA – 10,0 kV – 750 rev/min



Model of Synchronous
Condenser "Moron"
30 MVA – 13,2 kV – 1000 rev/min

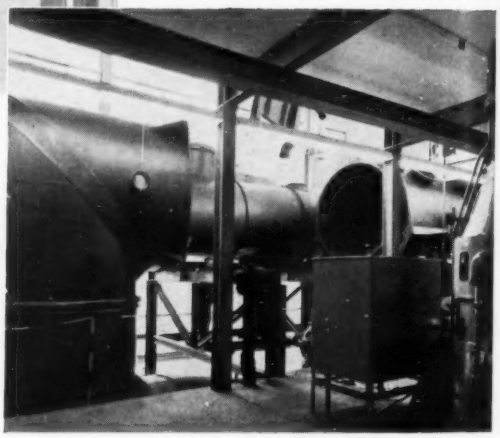
ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)



The main plant in the new laboratory is the large flume through which water flows to the turbine model.

Erection of the cavitation tunnel. The tunnel is intended for tests with large turbine models of Kaplan or propeller type.



KMW's new Turbine Laboratory at Kristinehamn -one of the best equipped in the world

The water power of the world is being exploited at an ever increasing rate. Turbines are being further developed and new types are appearing. The size of the average unit is increasing and greater demands are placed on performance. This calls for constant research and development work.

In this connection KMW as turbine manufacturers are well to the fore and for a long time past have maintained their position among the world's leading concerns in this field by extensive technical development work, above all in respect of the hydraulic design of the turbines. In order to intensify this activity still more, a completely new hydraulic laboratory has recently been put into service. The stationary equipment consists at present of three main units: an open flume circuit, where large model turbines can be tested under a head of 4 m, and two separate cavitation tunnels. One of the tunnels is intended for tests with models of high pressure turbines under heads up to 100 m, while the other, which like the flume has been proportioned for large scale models, is adapted for tests with low heads and large volumes of water. Controls and instrument readings are centralized. The measuring equipment is to a large extent electronic and permits great accuracy and rapid tests.

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KMW

St. Fillans Power Station
Consulting Engineers:
Sir M. MacDonald & Partners

underground power stations

Ceannacroc Power Station
Consulting Engineers:
Sir W. Halcrow & Partners

The illustrations show views of the first two major Underground Power Stations to be commissioned in the British Isles. Both of these stations were constructed by the Mitchell Construction Co. Ltd. as part of the numerous contracts carried out by them for the North of Scotland Hydro-Electric Board.

MITCHELL CONSTRUCTION

building and civil engineering contractors

THE MITCHELL CONSTRUCTION COMPANY LTD

Wharf Works, Peterborough

P.3051

Orders received during 1958

Plant	No. & type of turbines	D nom mm	H norm. m	HP totally	n
Valajaskoski	2 Kaplan	6.500	11.2	67.800	75
Aittokoski	1 Kaplan	4.450	25.8	46.900	143
Juukoski	2 Kaplan	5.700	24.5	148.000	115

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AKTIE-BOLAG ENGINEERING WORKS

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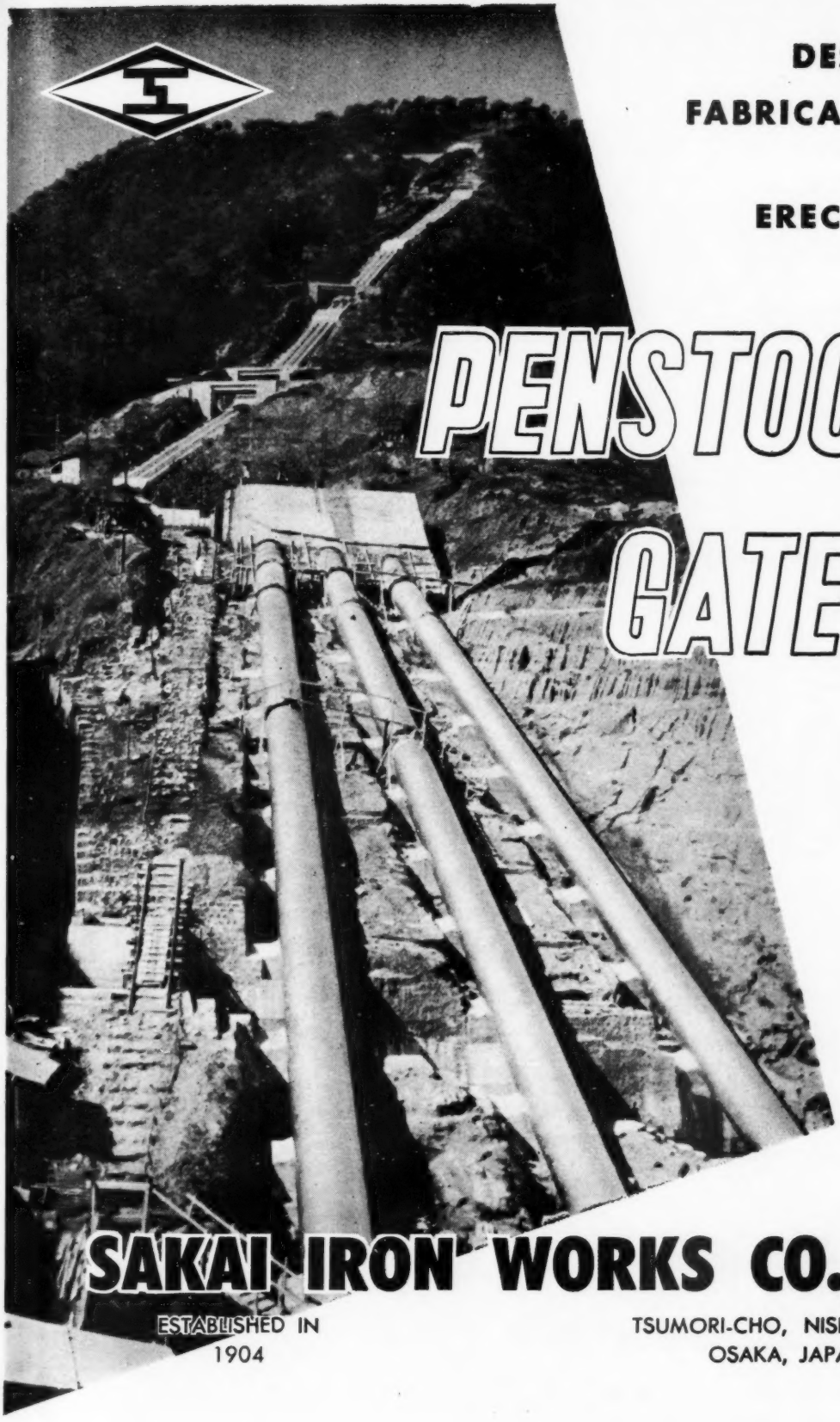

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FIXED BLADE PROPELLER
ADJUSTABLE BLADE PROPELLER
AND IMPULSE TYPE TURBINES

. . . Canadian Vickers supplies and services complete Leffel Turbines and large Turbine components.

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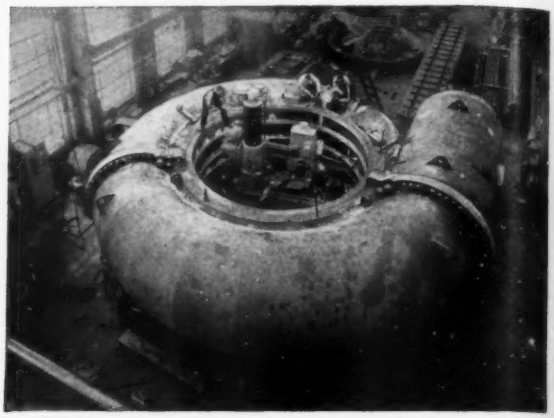
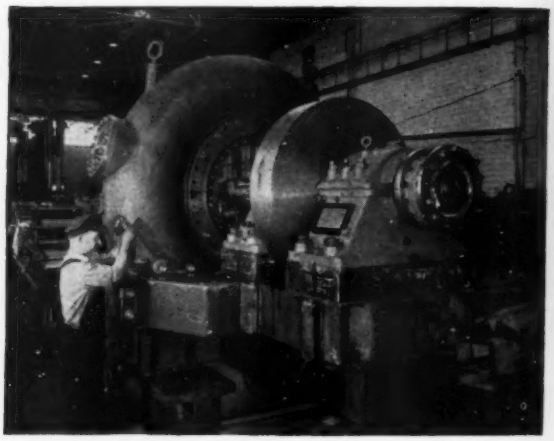
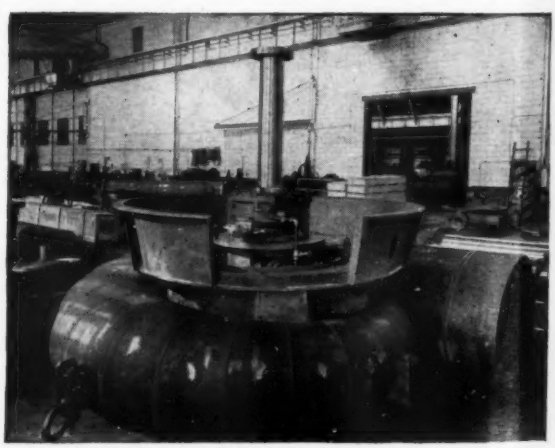


Scroll Case for 150,000 H.P. Neyrpic Turbine working under 785′ Net head, being machined in our shops.



A Horizontal Shaft Leffel Turbine rated 3,200 H.P. under 425′ Net head, partly assembled.



Shop assembly of Vertical Leffel Turbine rated 3,000 H.P. under 125′ Net head.

CP

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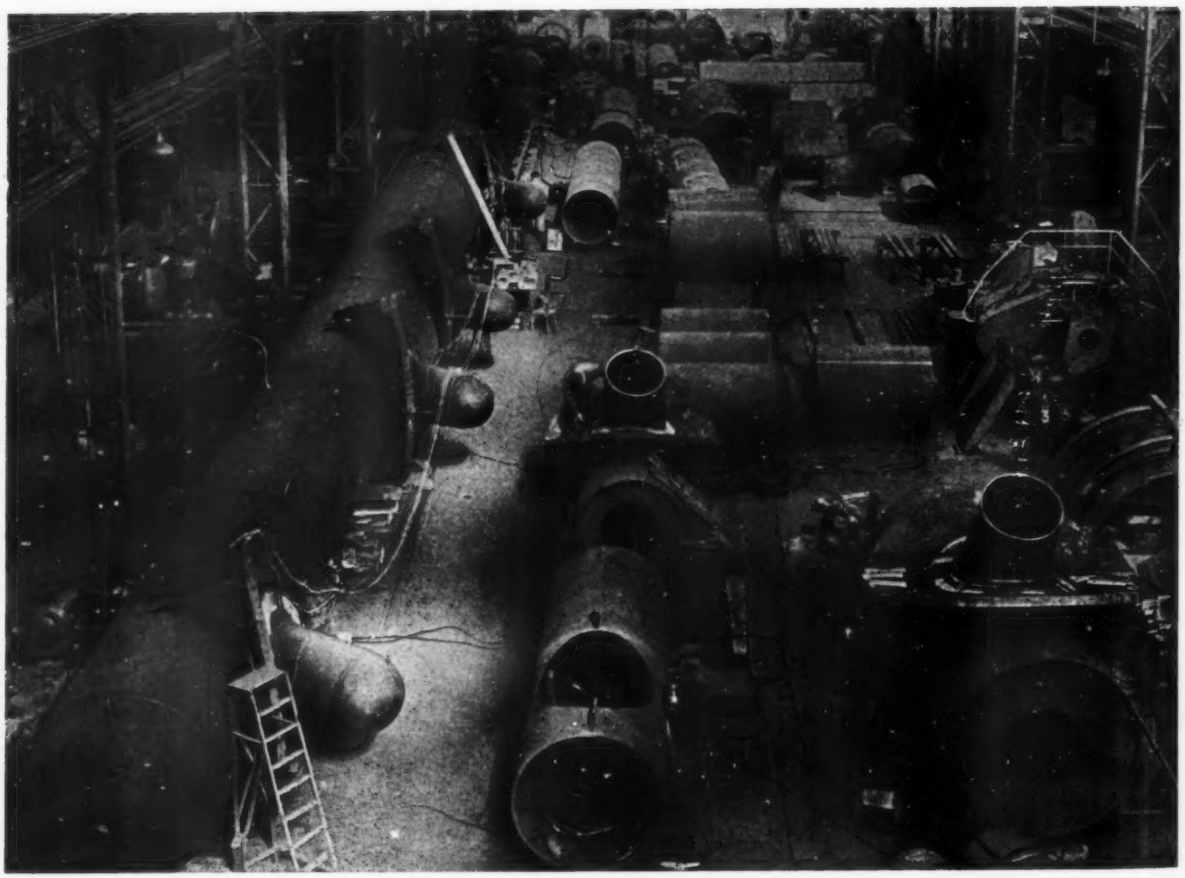
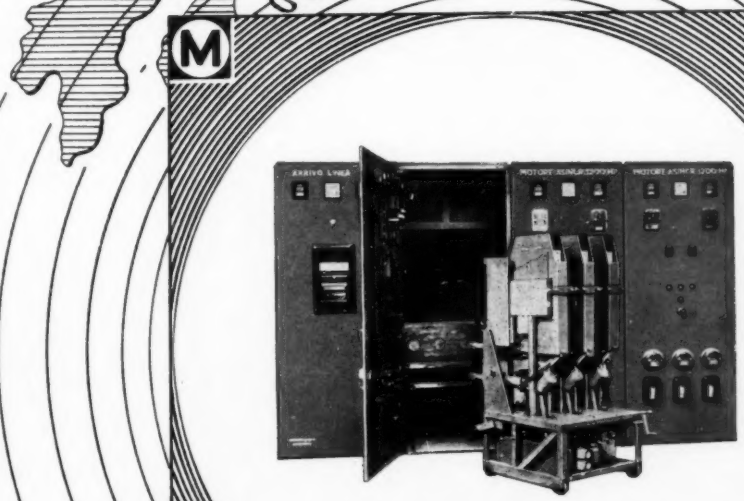
Rated voltages: 10 - 15 - 20 - 30 KV
Bus-bars rated currents: 600 - 1000 - 2000 Amps
Circuit breaker rated currents: 600 - 1200 - 2000 Amps
Symmetrical breaking capacities: 300 - 600 - 1000 MVA

Penstocks, pressure shafts linings,
Substation steel structures
Gantry and overhead travelling cranes
Pylons, water gates



Downstream portion of the Grande Dixence Fionnay Power Station distribution pipe during tensometric shop tests. Max. wall thickness 52 mm., service pressure 96 at., test pressure 121 at.

GIOVANOLA **Monthey - Switzerland**

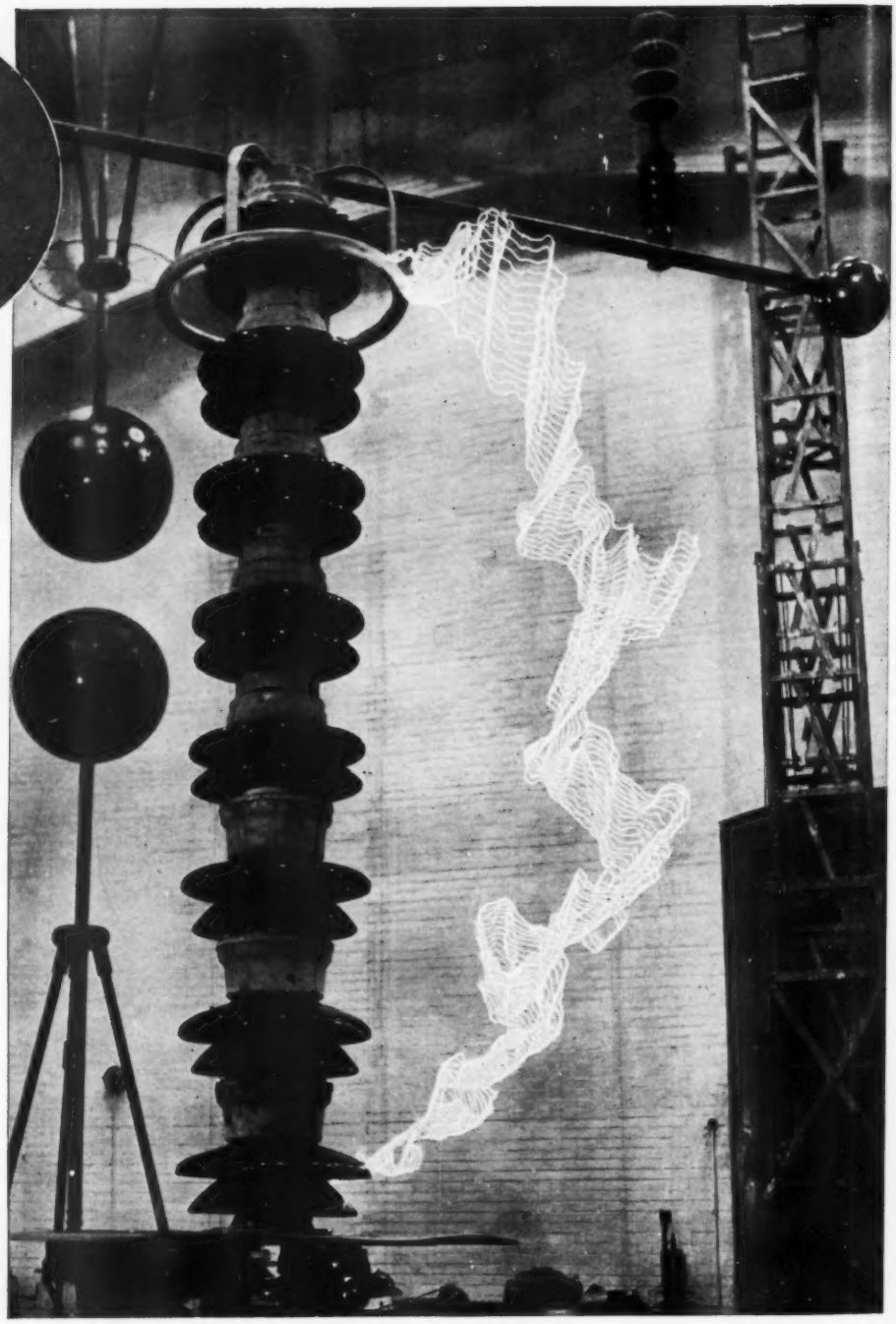


Metal-clad switchgear for indoor operation equipped with de-ion air circuit breaker DH in the draw-out execution.

MAGRINI'S TRADE-MARK AND SWITCHGEAR WIN WORLD-WIDE RECOGNITION

MAGRINI S.P.A. - VIA L. MAGRINI 7 - BERGAMO - ITALY

275kV. post insulators for the British Supergrid



One of the S.P.P. 8-unit post insulators for the C.E.G.B. 275 kV Supergrid undergoing the 50-cycle flashover test at 705 kV during the official type tests carried out at the million-volt laboratory at Stourport-on-Severn.

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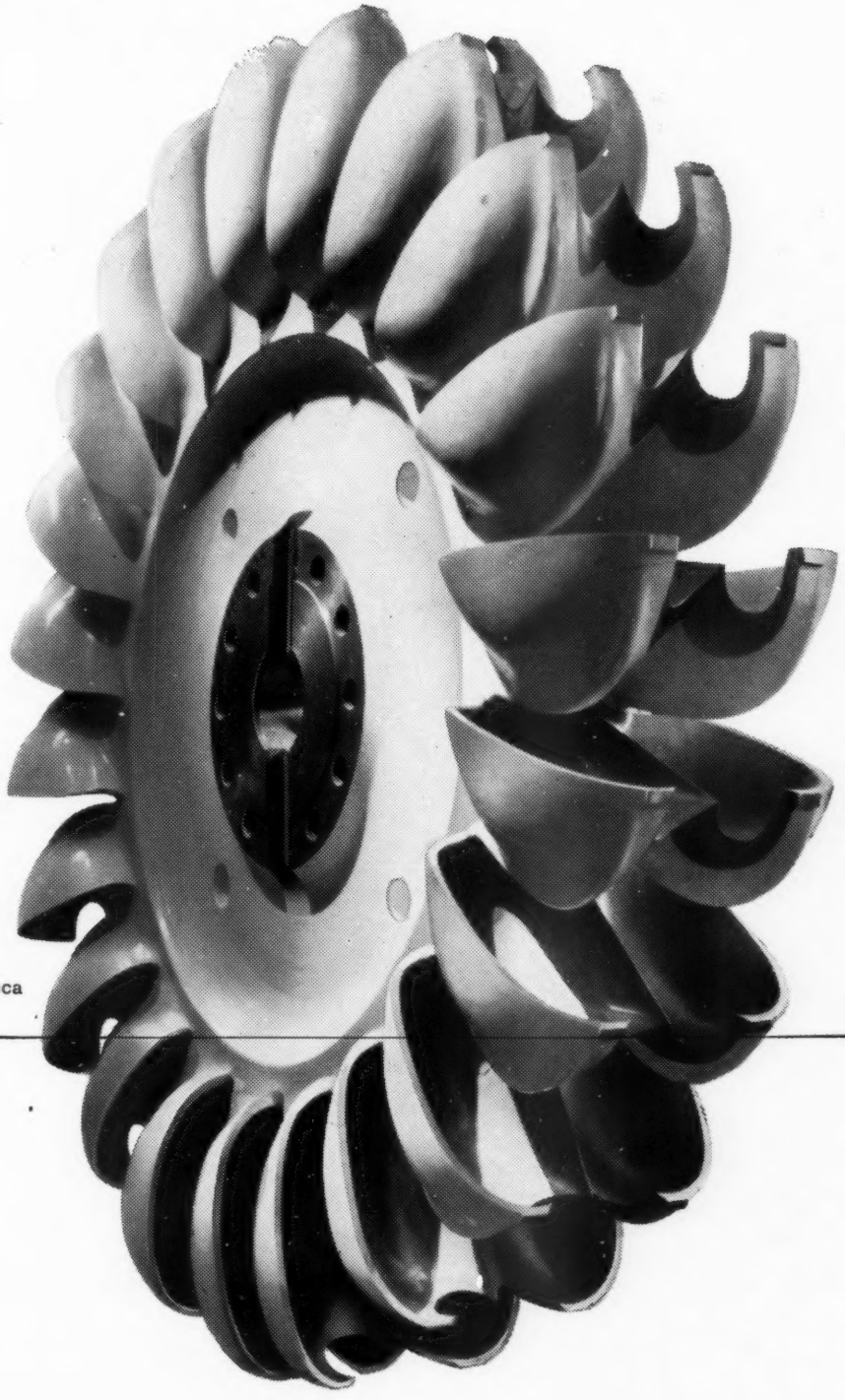
has the following large impulse turbines in course of execution for Swiss installations

	Head in metres	Unit output HP
Castasegna	**710**	**45 000**
Loebbia	**730**	**47 000**
Tavanasa	**480**	**67 000**
Biasca	**700**	**110 000**
Tierfehd	**1030**	**125 000**

Escher Wyss Ltd., Zurich/Switzerland



One of the runners for Biasca

Apparatus Department

CANADIAN GENERAL

without a magnificently powerful heart
to sustain his all-out effort, a great racehorse
would never reach the finish line

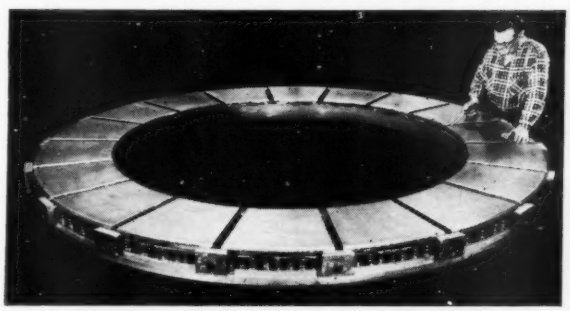
BUILT LIKE THE HEART OF A GREAT RACEHORSE

The heart of a racehorse and a hydro-electric generator's thrust bearing are surprisingly alike. The thrust bearing supports all the generator's rotating parts and sustains the force of the hydraulic thrust developed . . . all on a film of oil no thicker than a sheet of paper! For example, the thrust bearing of every G-E Generator at the St. Lawrence Seaway Power Project supports a total weight of 3,000,000 pounds. *No other single component is so important to a generator's longevity and success in the race to keep up with our ever growing need for low-cost electric power.*

Canadian General Electric's first hydro-electric generator went on the line sixty years ago. It is still operating and has been followed by over 600 others. To a large degree, the reputation they have built for uninterrupted power production is due to C.G.E.'s precompressed-spring-mounted bearing design. This design has evolved gradually and surely through the years from continuous, extensive research and prototype testing carried out at the C.G.E. Peterborough Works.

A fine print of the original artwork used in this advertisement, suitable for framing, is available on request. Write to: Advertising and Sales Promotion, Apparatus Department, Canadian General Electric Co. Ltd., Peterborough, Ont.

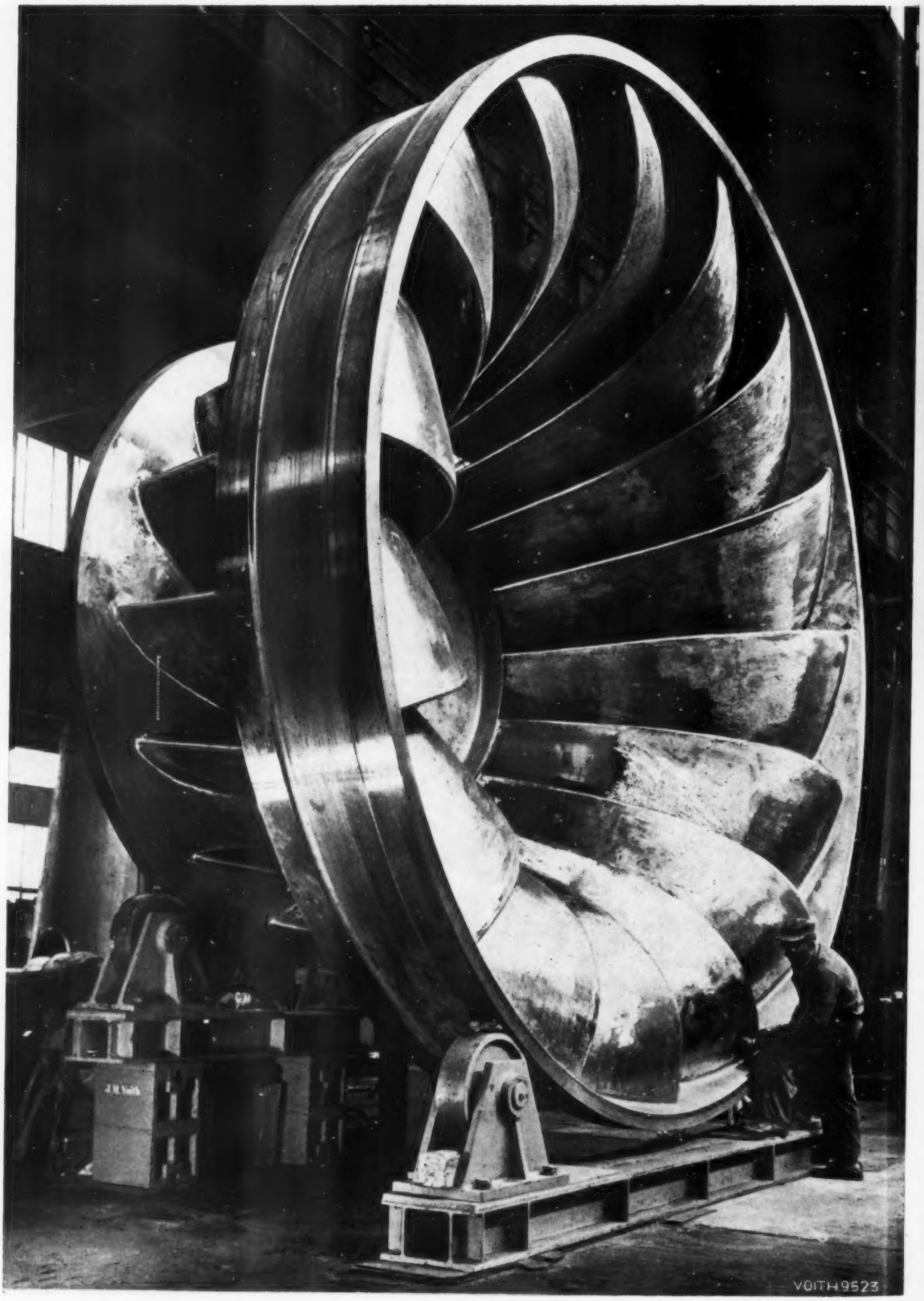
GENERAL ELECTRIC
GENERATORS



View showing the stationary members—base ring, precompressed springs and babbitted segments—of the thrust bearing for a G-E Hydro-electric Generator rated 165,000 kva, 0.9 PF, 200 rpm, 13,800 volts.

ELECTRIC COMPANY LIMITED

AAD-9204-58301



The first of six Voith Francis Turbines in operation since May, 1959, in the MACAGUA HYDRO-ELECTRIC POWER STATION on the Caroni River (Venezuela). The photo shows workshop grinding of a Macagua runner, max. dia. about 17½ ft. Output of each turbine 87,200 h.p. under 132 ft. head.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY

General Electric's extra high voltage towers will be 160 feet high and 180 feet wide. Model towers shown above are built to 1/25 scale. A model of an ordinary tower is also shown.

The world's largest bushings, for 650-kv power transformers, will be used in G. E.'s prototype EHV system.

For long-range power planning...

GENERAL ELECTRIC ANNOUNCES PROJECT EHV—A NEW CONCEPT IN SUPER VOLTAGE POWER TRANSMISSION

Here's news from General Electric that could affect long-range plans for power development in many parts of the world. It's project EHV—Extra High Voltage. Right now, General Electric is building a system that will transmit electricity at voltages higher than ever before. The system is scheduled to carry power at a maximum of three-quarters of a million volts—higher than any existing power line in the world. Later the line may be altered to send up to a million volt power.

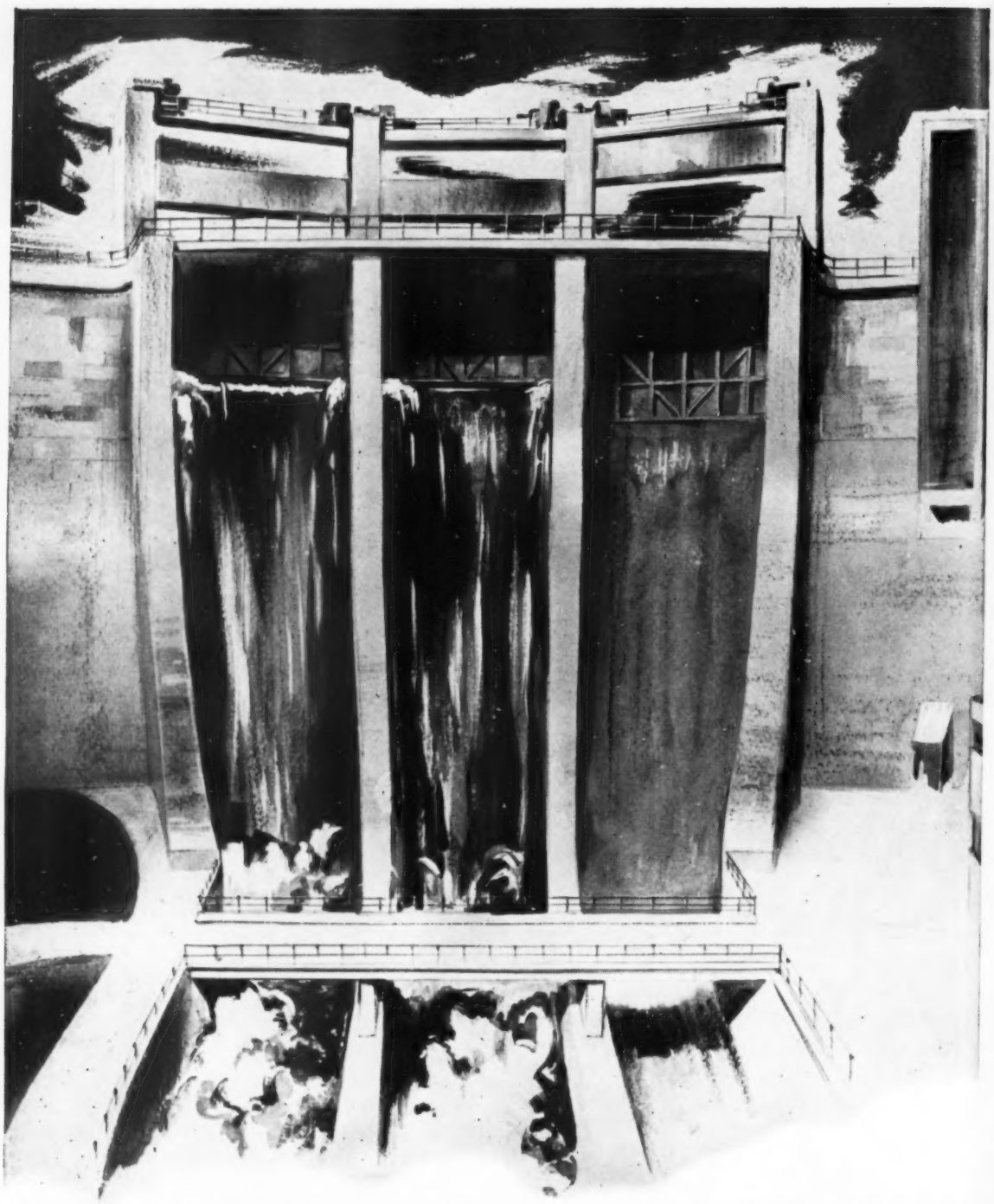
The entire electrical power industry is expected to benefit from this project. In the future, more and more of the world's great cities will be able to "bring in" low cost power from distant water power sites. This will not only speed economic growth in many countries, but it will also help conserve precious fuel supplies.

Project EHV is a five-year program designed to provide actual operating experience and other valuable information on extra-high voltage transmission. It is another in a long series of General Electric developments that have earned G. E. its reputation for designing and manufacturing reliable products for utilities throughout the world. *International General Electric Company, Dept. 59-5E, 150 East 42nd Street, New York 17, N.Y., U.S.A.*

Progress Is Our Most Important Product

GENERAL ELECTRIC

—U.S.A.—



TO DOUBLE THE POWER OF ROXBURGH

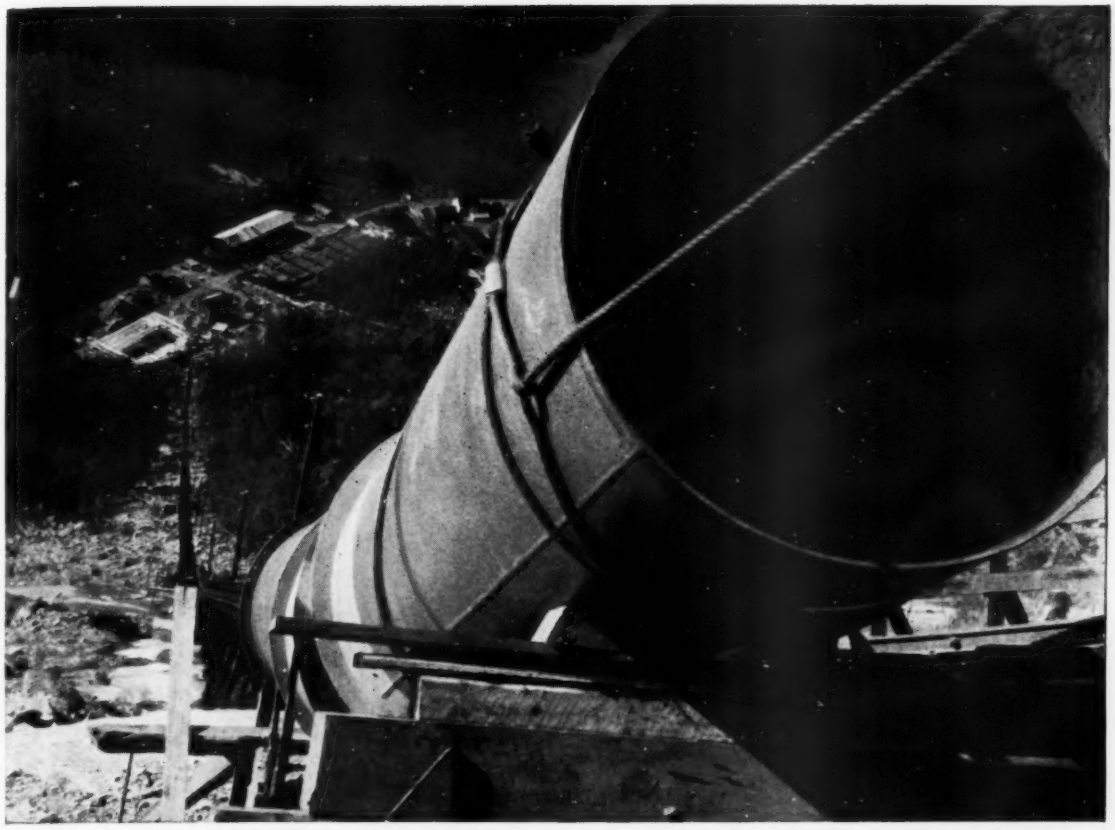
AEI

Four AEI waterwheel alternators at the New Zealand Electricity Department's Roxburgh Power Station are already feeding 160,000 kW into the South Island grid. Four additional sets, to bring the station up to its designed capacity of 320,000 kW, are now in course of construction.

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

HEAVY PLANT DIVISION — RUGBY AND MANCHESTER, ENGLAND

A 5179



Pipe Line for the Maageli Power, Tyssedal, Norway

MANNESMANN

furnish penstocks

of all sizes and for all pressures
for both grouted and supported pipe lines

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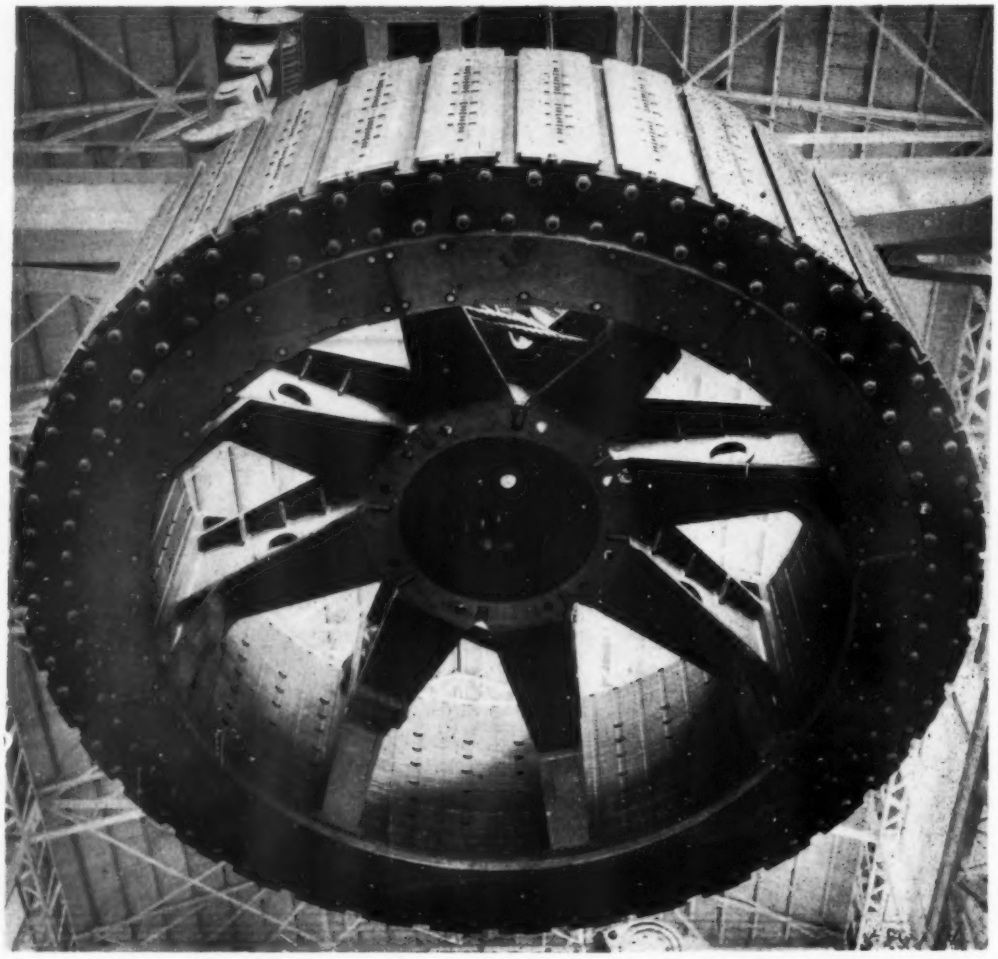
DÜSSELDORF · GERMANY
Representatives all over the world.



Massive AC Generator for Brazil

Capacity	Voltage	Frequency	Speed
83,000 KVA	13.8 KV	60 cps	200 r.p.m.

The two largest AC generators ever built in Japan for export were completed by Hitachi last January. They were destined for the Paulo Afonso Power Station of Compannia Hidro Electrica Do Sao Francisco and situated on Brazil's San Francisco River — the hub of a gigantic hydro-power grid serving northern Brazil, with a capacity of 1,000,000 KVA.

These umbrella-type alternators incorporate a number of new developments. The rotor spider, for example, was constructed of welded steel to effect a considerable reduction in rotor weight. A new, synthetic resin gives added durability and insulation for the coil. The segment-type bearings eliminate the need of an oil pump. These and other improvements are products of the world's most advanced electro-mechanical technology.

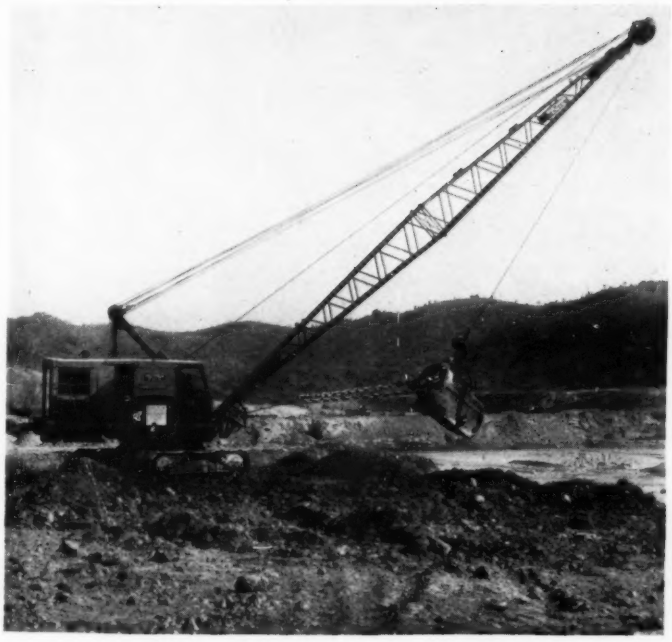
Hitachi, Ltd.

Tokyo Japan

Cable Address: "HITACHY" TOKYO

In Turkey . . .
and the world over

Bucyrus-Erie excavators are identified with progress



Whatever its form, the development of resources for a nation's progress begins with excavation. But hand excavation is slow and costly and today large schemes are only practical because of the advantages of modern large-scale mechanical excavation whether it be in open-cast mining or public works. Hydro-electric power schemes to utilise the natural resources of a country involve the excavation of immense quantities of earth and rock. Shown are two of the five 54-B machines used by Association EMC-RAR on dam construction work at Demirköprü. The Hydraulic Works Administration justifiably put their faith in Bucyrus-Erie.

BUCYRUS ERIE

BUCYRUS-ERIE COMPANY
South Milwaukee, Wisconsin, U.S.A.

RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

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BELGIUM CONGO

FOUR 89 500 HP VERTICAL-SHAFT FRANCIS TURBINES
operating at 333 r.p.m. under a 179 m. head

hydraulic turbines

equipment of large dams and hydro-electric power plants

equipment of irrigation networks

drilling turbines

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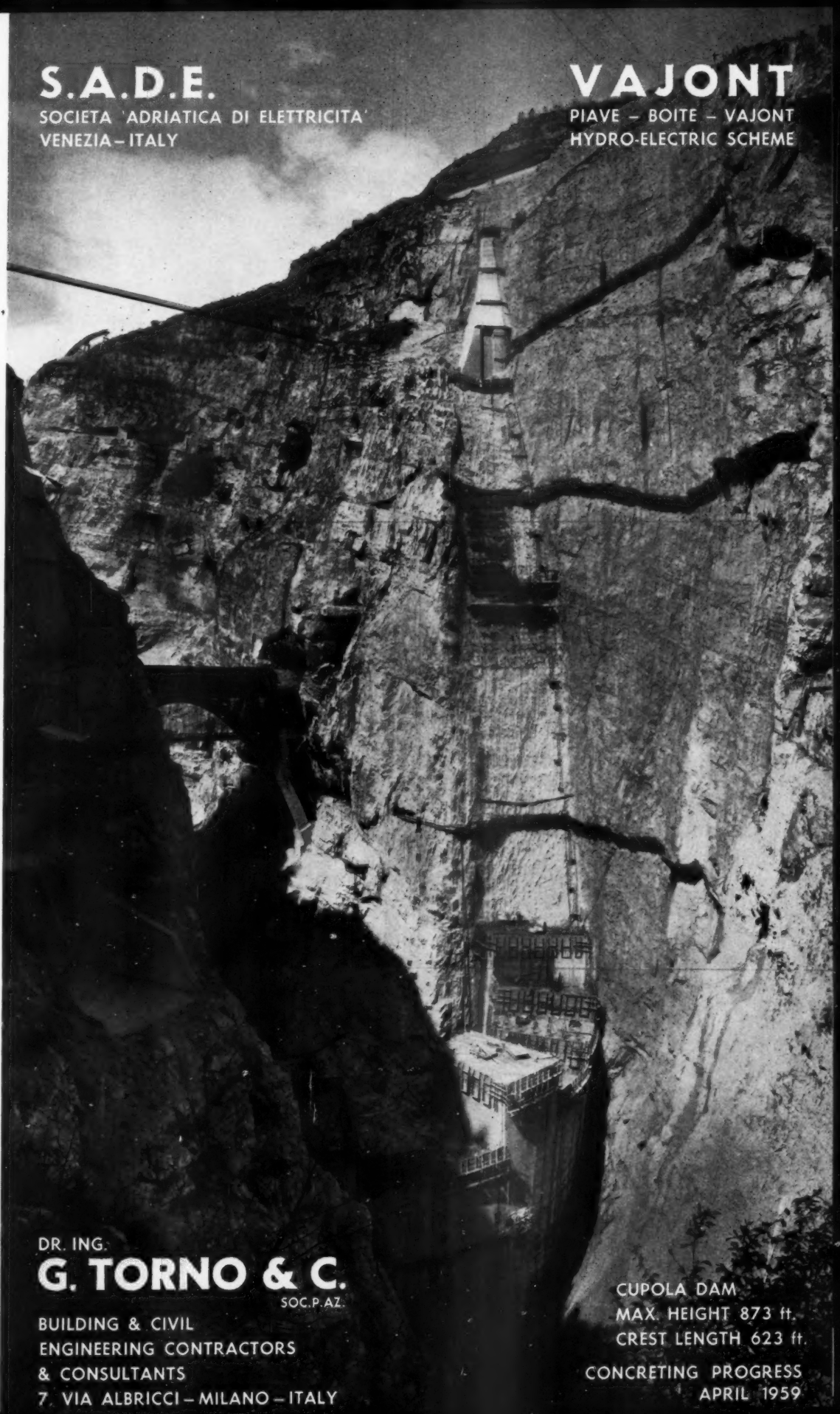
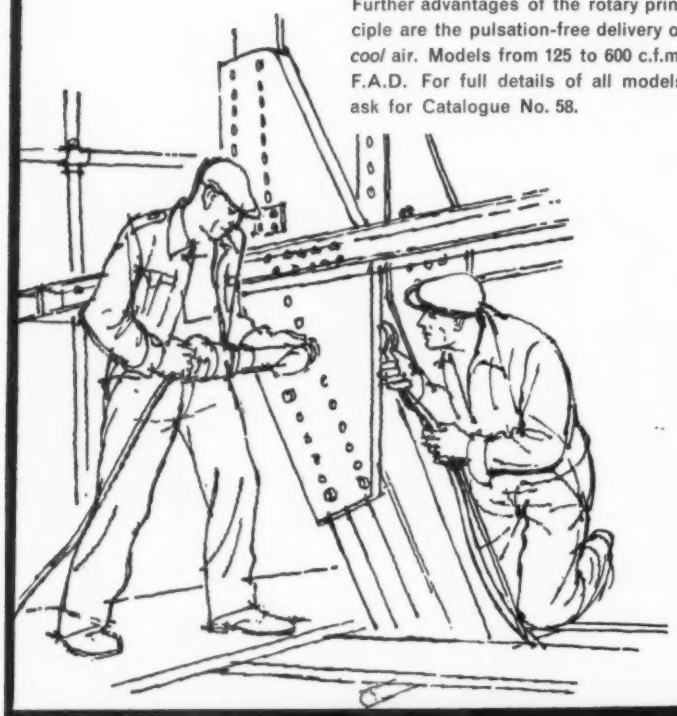

S.A.D.E.
SOCIETA 'ADRIATICA DI ELETTRICITA'
VENEZIA – ITALY
VAJONT
PIAVE – BOITE – VAJONT
HYDRO-ELECTRIC SCHEME
DR. ING.
G. TORNO & C.
SOC.P.AZ.
BUILDING & CIVIL
ENGINEERING CONTRACTORS
& CONSULTANTS
7, VIA ALBRICCI – MILANO – ITALY
CUPOLA DAM
MAX. HEIGHT 873 ft.
CREST LENGTH 623 ft.
CONCRETING PROGRESS
APRIL 1959

THIS is the compressor that costs less to operate: the "Power Vane" Rotary. The essential simplicity of the rotary principle, pioneered by Consolidated Pneumatic, ensures rock-bottom maintenance costs: there are no valves, pistons, clutch or crankshaft to service, and the few wearing parts run in oil. Further advantages of the rotary principle are the pulsation-free delivery of *cool* air. Models from 125 to 600 c.f.m. F.A.D. For full details of all models ask for Catalogue No. 58.



POWER VANE
ROTARY COMPRESSORS

Cost less to operate

CP186

MANUFACTURED BY
Consolidated Pneumatic

CONSOLIDATED PNEUMATIC TOOL CO LTD • DAWES ROAD • LONDON • S.W.6

Dust Suppression for all Drilling Operations

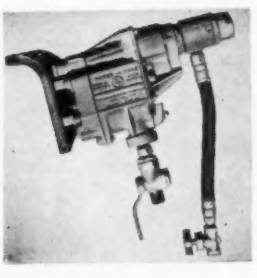
The Hemborn Dust Extractor works on a new principle

By the creation of a vacuum immediately at the drill tip, the Hemborn Dust Extractor not only takes the dust and cuttings from the actual seat of operation, but is also all the time filtering the immediate atmosphere. There is virtually no escape of dust when the Hemborn Dust Extractor is in use.

Full details of this outstandingly effective equipment are given in literature free on request.

Wet Rotary Drilling

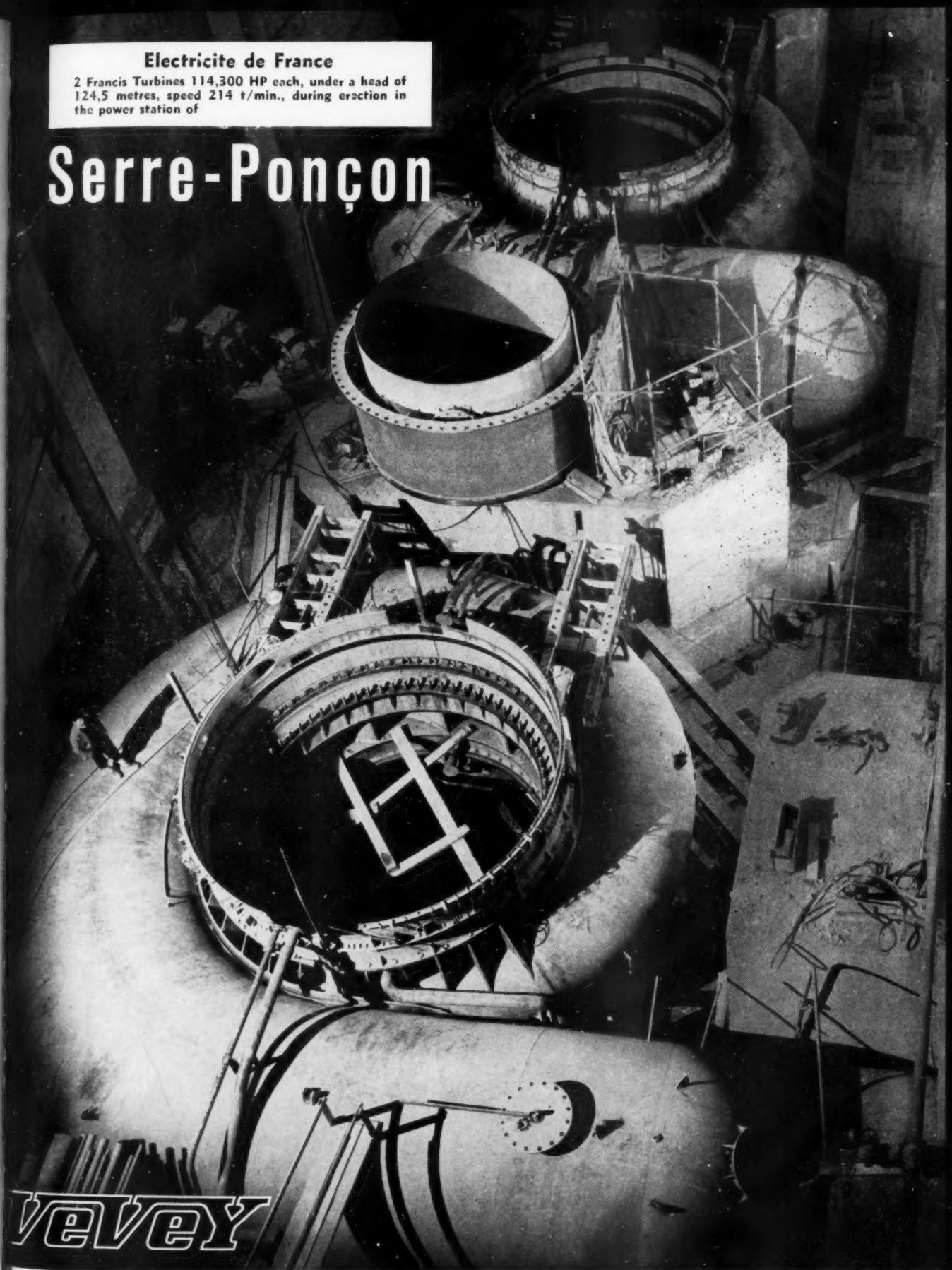
The powerful No. 327 pneumatic coal drill designed for wet drilling has a forward water feed giving unrestricted flow through the drill rod without leakage back to the operator. This tool is available as a dry model and in both versions there is a choice of speeds. CP boring tools include electric models which can also be fitted with wet drilling attachment.



Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon

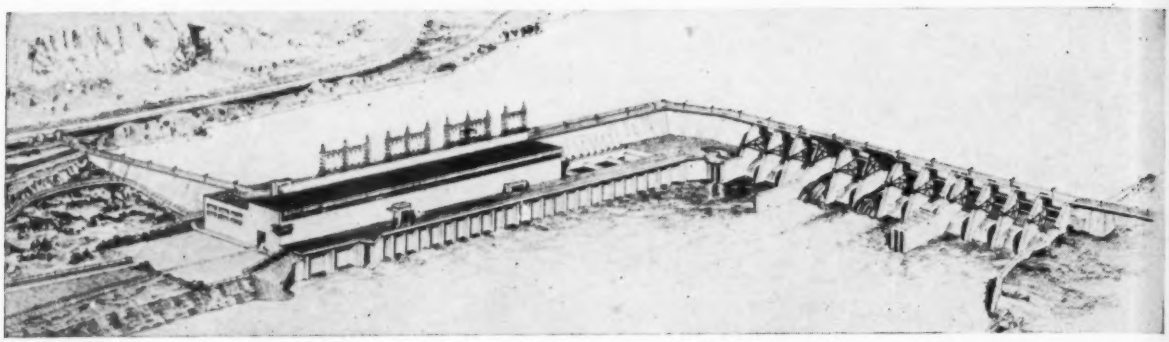


Vevey

Vevey Engineering Works Ltd.

Vevey (Switzerland)

in collaboration with our French licensee:
Cie des Ateliers et Forges de la Loire, St-Chamond (Loire)

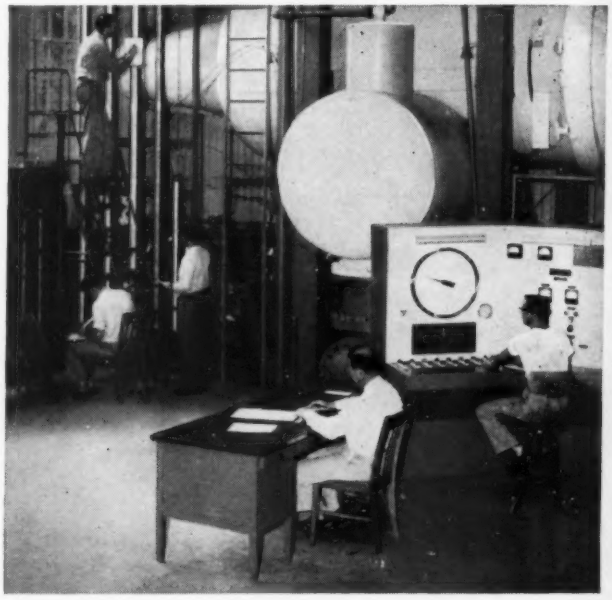


Rocky Reach Hydroelectric Project, under construction on the Columbia River by Public Utility District No. 1 of Chelan County, Washington. Stone & Webster Engineering Corp. are Engineers and Supervisors of Construction. The installation is downstream from Chief Joseph Power Project, where six 100,000 HP vertical Allis-Chalmers Francis units are installed.

Homologous models for Rocky Reach were tested in the York Works Hydraulic Laboratory under controlled conditions that duplicate those in protoype field installations.

ROCKY REACH TO USE ALLIS-CHALMERS KAPLAN TURBINES

High-capacity units to be equipped with special new Runaway Speed Limiter



Rocky Reach Hydroelectric Project, scheduled to generate electricity in 1961, will be powered by seven Allis-Chalmers Kaplan turbines. These 280-inch units are each rated at 140,000 HP under a 92-foot head, with maximum expected capacity exceeding 160,000 HP under a 98-foot head. This new high-capacity design, with greatly improved cavitation characteristics, was developed by Allis-Chalmers engineers at the York Works and tested in the high head test stand there.

Each unit will be equipped with a special new turbine Runaway Speed Limiter, which will make it impossible for a speed of more than 85% over normal to be attained. The possibility of excessive overspeeds of 150-200%, previously an accepted characteristic of Kaplan-type turbines, is positively eliminated. A substantial saving in the cost of generators resulted from this new method of speed limitation.

Its feasibility was proved by laboratory and field research. Field acceptance tests on installations equipped with the Runaway Speed Limiter have confirmed its complete dependability and effectiveness.

You can look to A-C for the latest design, engineering and manufacturing advances in hydraulic turbines and accessories. For information, write to Allis-Chalmers, Hydraulic Division, York, Penna.

Hydraulic Division RESEARCH DESIGN HYDRODYNAMICS ENGINEERING FABRICATION

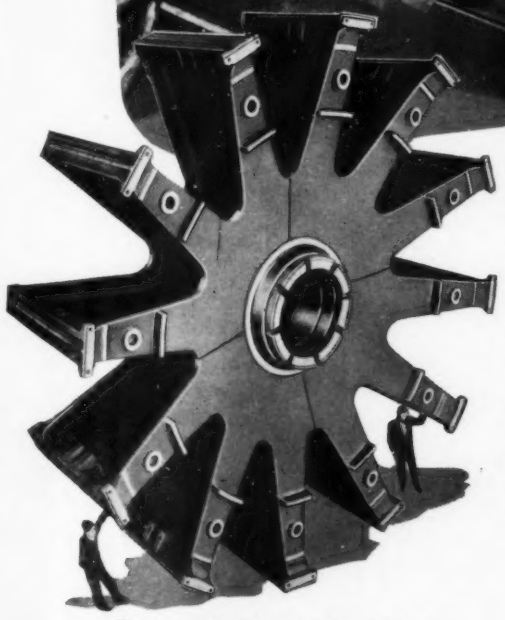
Hydraulic Turbines & Accessories • Pump-Turbines • Pumps • Liquid Heaters

Rotovalves • Ball Valves • Butterfly Valves • Free-Discharge Valves

AC ALLIS-CHALMERS

1100

The stator frame of one of the three 150,000 kVA generators for the Stornorrfors Power-station, Sweden. The total weight of the generator is 925 tons.



The rotor spider with a diameter of 8.36 metres and a weight of 86 tons for one of the Stornorrfors generators.

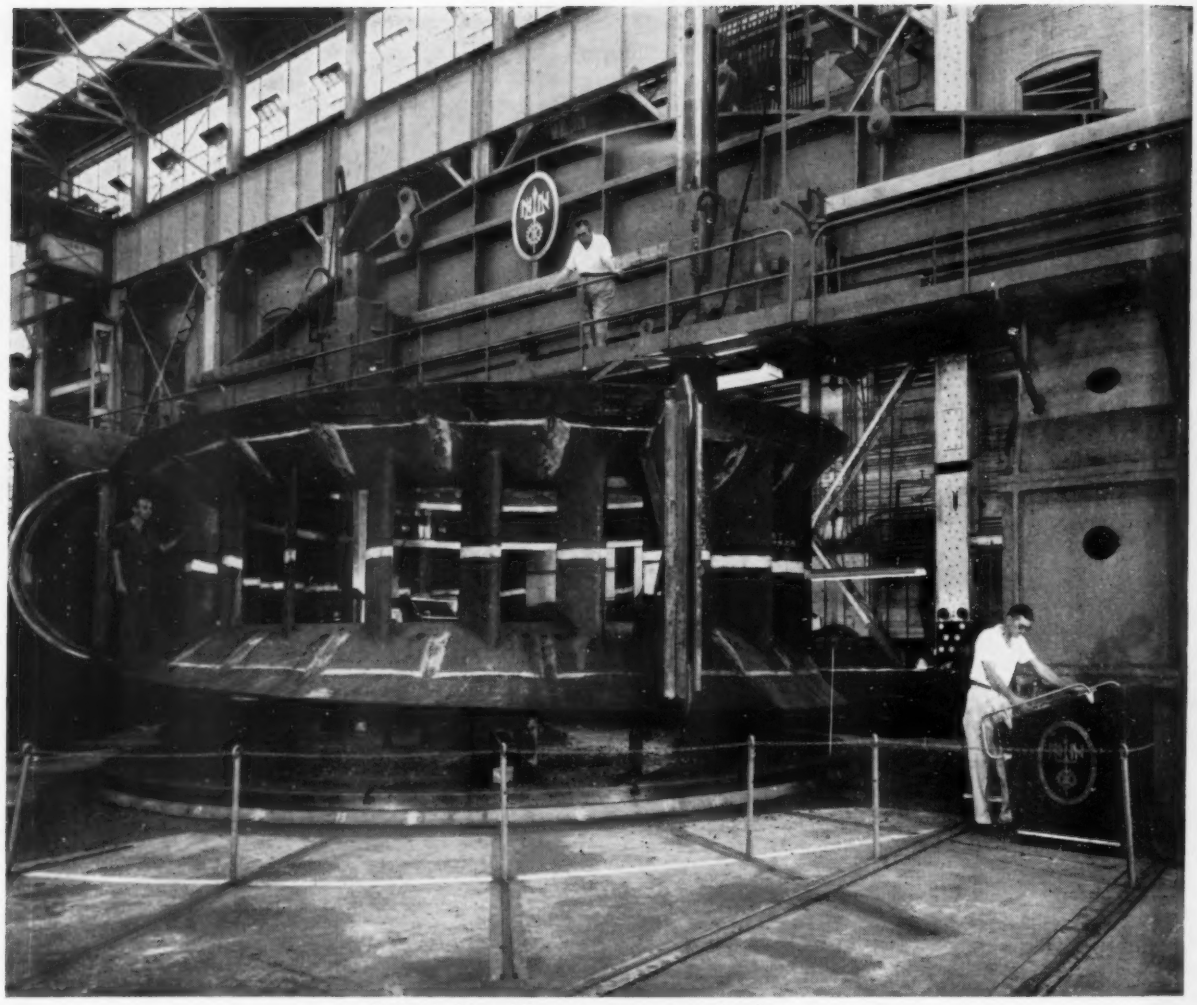
Power in the making

In Sweden water power is abundant, and practically all of the country's power production—which is notably high—emanates from ASEA Generators.

The building of electric equipment for hydro-electric power stations has been one of ASEA's main activities for more than 75 years. Recently ASEA has supplied three 150,000 kVA generators for a Swedish power station, and for stations abroad ASEA-units of water wheel generators built after the war, or under way, amount to a total of about 2,000,000 kVA.

A visit to these stations would mean a full round-the-globe trip!—So we think ASEA might be able to solve even your power problems. We have the experience and the resources.

Västerås **ASEA** **Sweden**



42 ft. boring mill-rough cuts a stay ring for one of the world's most powerful hydraulic turbines.

Newport News builds six king-size turbines for Niagara Power Project

These skilled Newport News machinists are milling a stay ring for one of six 200,000 hp. Francis-type hydraulic turbines. Before they're finished, they'll turn out five more turbines—the world's most powerful—for the Lewiston Power Plant of the Niagara Project.

Newport News has not only the men, but the facilities to take a job like this in its stride . . . your job, too. For example, the 42 ft. boring mill pictured above was designed and built at Newport News.

The large engineering and technical staffs, acres of iron, brass and steel foundries, five huge machine shops, and additional specialized equipment make Newport News a leader in the production of hydraulic turbines, valves, gates, penstocks, and other water power equipment you need.

Consult Newport News engineers on preliminary design recommendations at no obligation.

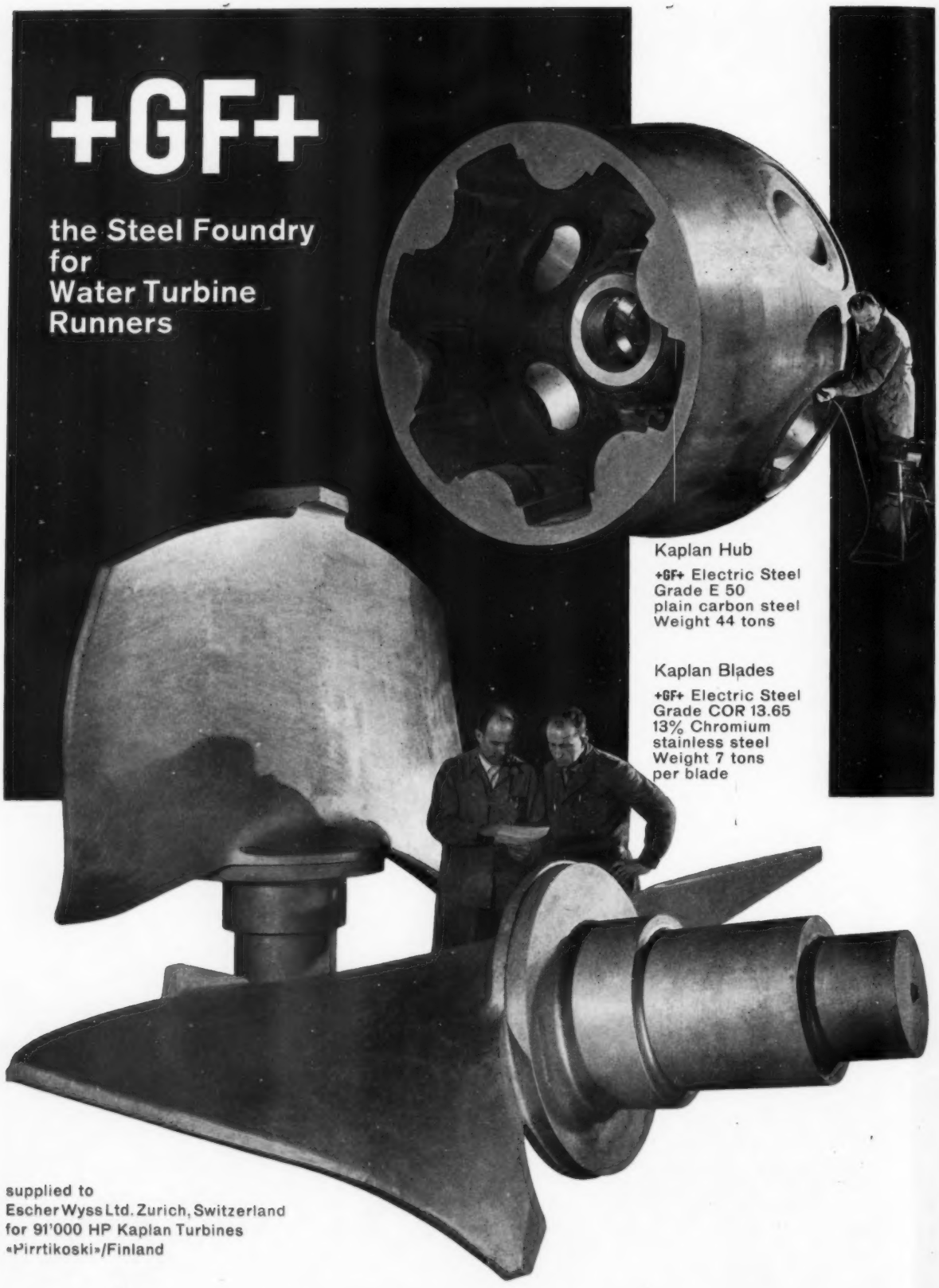
Engineers . . . Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News
Shipbuilding and Dry Dock Company
Newport News, Virginia

KVÆRNER
Now under construction—Four turbines
for Tokke 1 Power Plant, Norway.
Head - - 395 metres (1,200 ft.)
Output - - - - - 150,000 H.P.
Revolutions - - - - - - - - 375
Weight of Spiral Casing 110 tons
A. S. KVÆRNER BRUG, OSLO NORWAY

+GF+

the Steel Foundry for Water Turbine Runners



Kaplan Hub

+GF+ Electric Steel
Grade E 50
plain carbon steel
Weight 44 tons

Kaplan Blades

+GF+ Electric Steel
Grade COR 13.65
13% Chromium
stainless steel
Weight 7 tons
per blade

supplied to
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Question to Power Line Builders:

Is this your problem?

Simple? Maybe . . . but splicing electrical conductors — even if they are Feral Cable — has to be done properly if the finished line is to be a first-class job. In fact, the splicing is of A1 importance for the proper functioning of any transmission line. It is not only a matter of knowing how it should be done, but of seeing that the work is carried out correctly at every joint.

For good electrical connections, both the conductor wires and the aluminium sleeve have to be carefully cleaned before the splice is made. It is important, too, that the sleeve should extend for an equal distance on either side of the joint. Other precautions are also necessary, such as seeing that the steel core is not damaged when the outer layers of aluminium conductor are cut away.

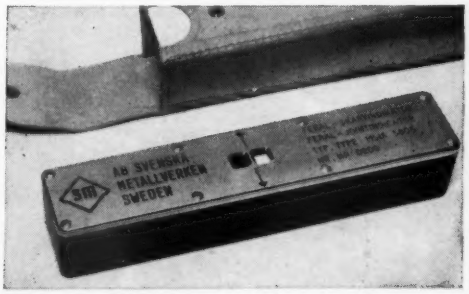
When customers are confronted with problems of line construction, Svenska Metallverken is always prepared to help in finding solutions by drawing on the extensive know-how which is available in Sweden. Come to think of it, there's a lot of know-how already gone in to making Feral Cable — *reliable* Swedish ACSR — available in such quantity and quality.

When planning power lines, consult

SVENSKA METALLVERKEN

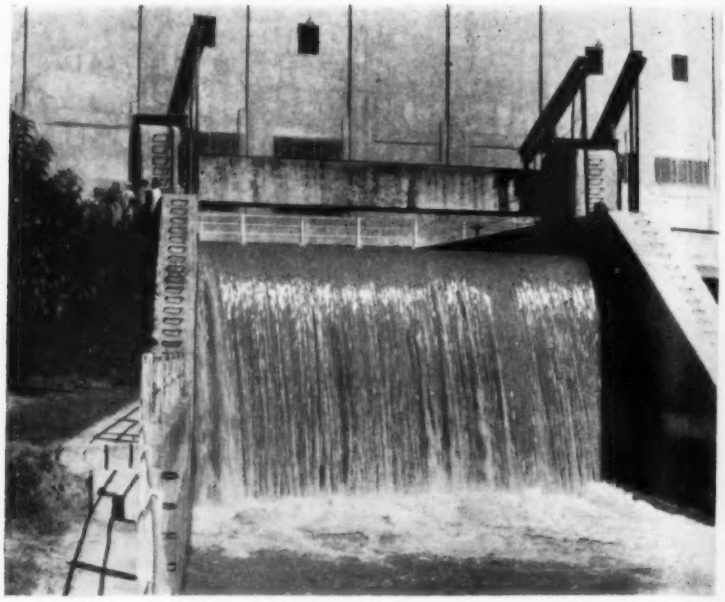
Manufacturers of Feral Cable

Job done properly? When once a sleeve has been clamped on, it may be difficult to see whether it has been properly positioned over the joint. To provide an easy method of checking, Svenska Metallverken has developed this Position Gauge, which shows, quickly and precisely, whether the sleeve is centred or not.



All tools and fittings necessary for ACSR line construction are supplied by Svenska Metallverken, in addition to the Feral Cable. When required, too, experts are sent out to help line builders with construction problems.

FERAL CABLE DIVISION SWEDEN VÄSTERÅS · SWEDEN



GLENFIELD GATES

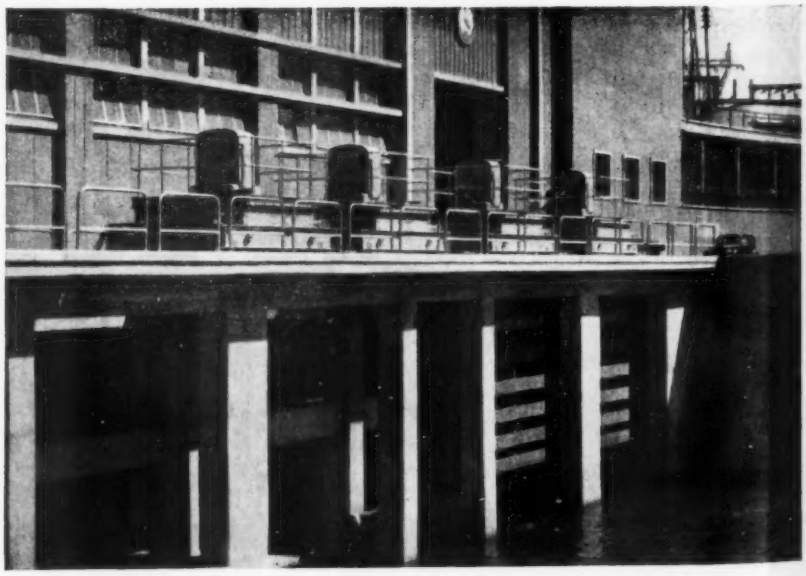
for Draft Tubes and Tailraces

In hydro-electric works where it is necessary to instal gates for sectioning-off the turbine draft tubes or for regulating the level in the tailrace, such gate requirements can be readily met from the Glenfield range. The above illustration shows one of three 42 ft. span x 7 ft. deep automatic Tilting Gates that control the tailrace level at Mohammedpur Power Station, India. Below are seen two of six 17 ft. 6 in. span x 14 ft. 7¾ in. deep Sliding Gates at the draft tube outlets of Owen Falls Power Station, Uganda.

Glenfield
GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office & Works : KILMARNOCK, SCOTLAND

VALVE SPECIALISTS AND HYDRAULIC ENGINEERS FOR OVER A CENTURY

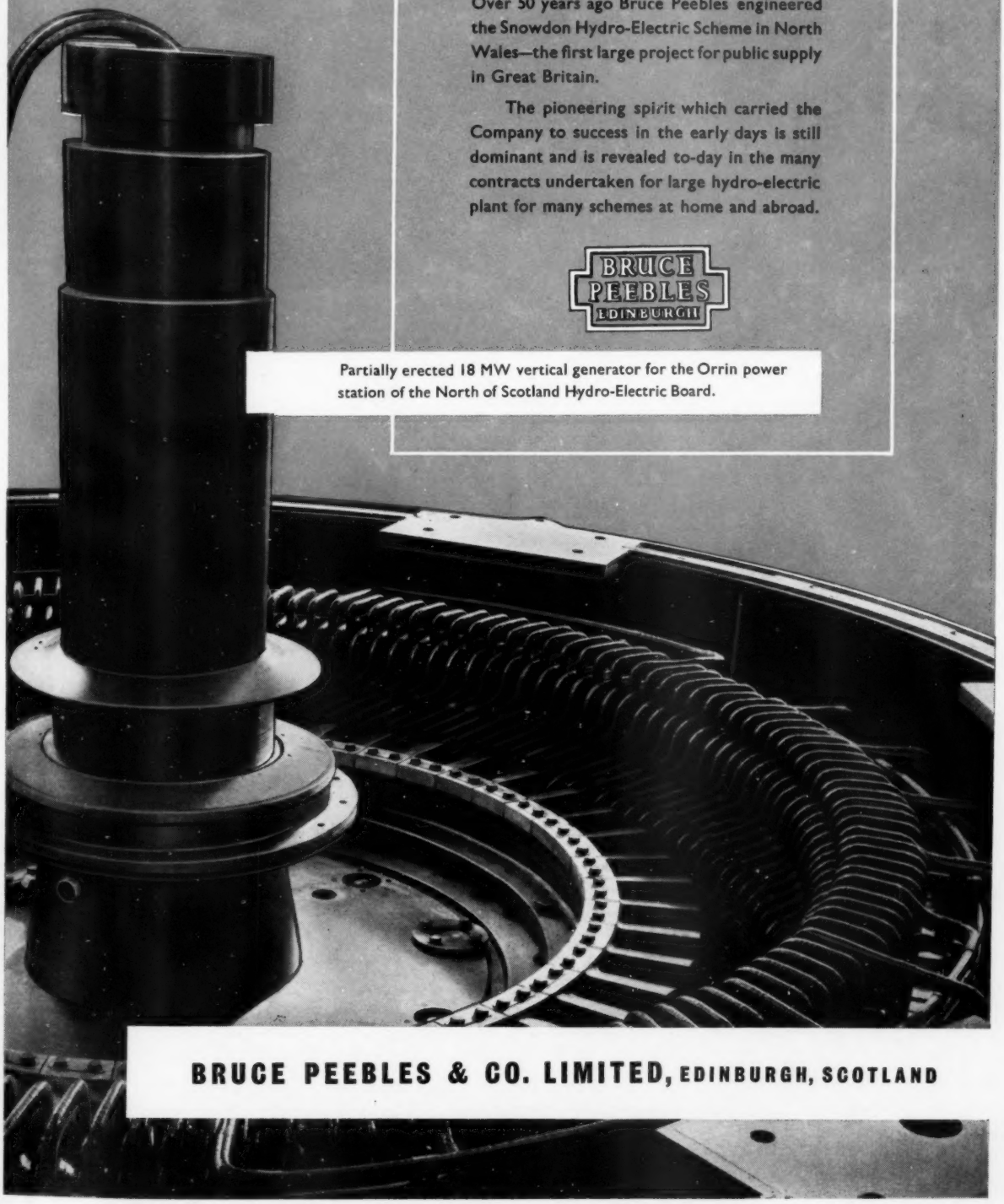


HYDRO-ELECTRIC GENERATORS

Over 50 years ago Bruce Peebles engineered the Snowdon Hydro-Electric Scheme in North Wales—the first large project for public supply in Great Britain.

The pioneering spirit which carried the Company to success in the early days is still dominant and is revealed to-day in the many contracts undertaken for large hydro-electric plant for many schemes at home and abroad.

BRUCE PEEBLES EDINBURGH



Partially erected 18 MW vertical generator for the Orrin power station of the North of Scotland Hydro-Electric Board.

BRUCE PEEBLES & CO. LIMITED, EDINBURGH, SCOTLAND

as one contractor to another—

you're on a good wicket with

Ingersoll-Rand

air equipment

BRITISH MADE

for full details and literature write to

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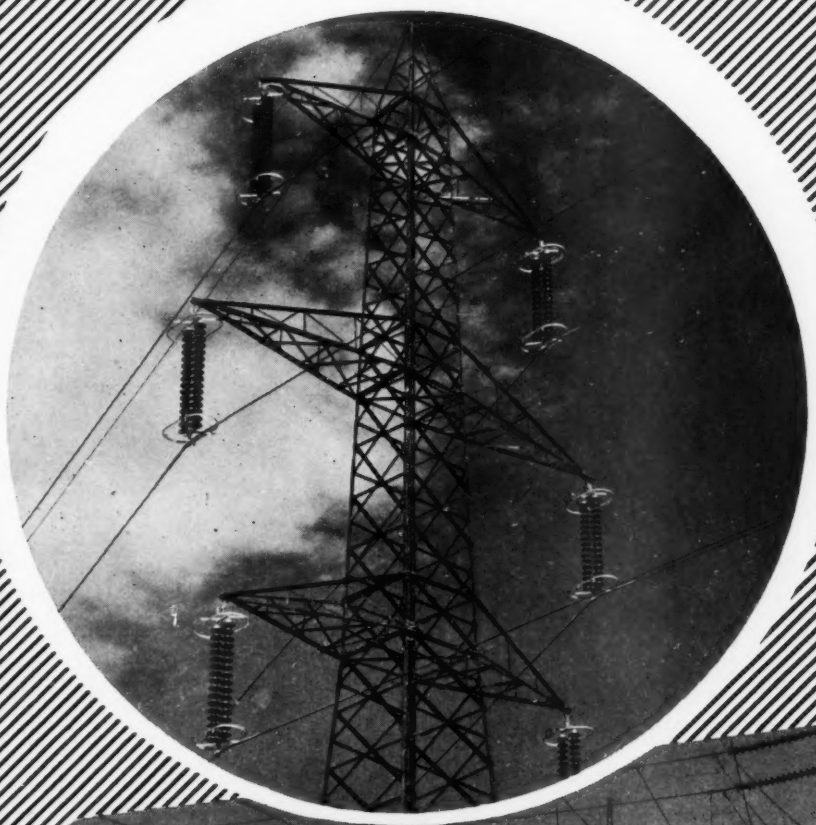
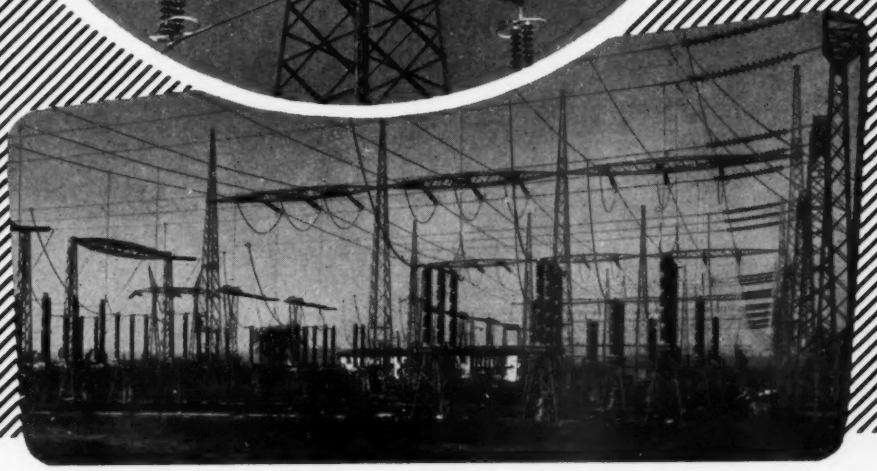
P642

SALVI





For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.

The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES (EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., 11 Kensington Church St., London, W.8

Telephones: WEStern 8857 and 4412 Cables: ENSALVICO LONDON

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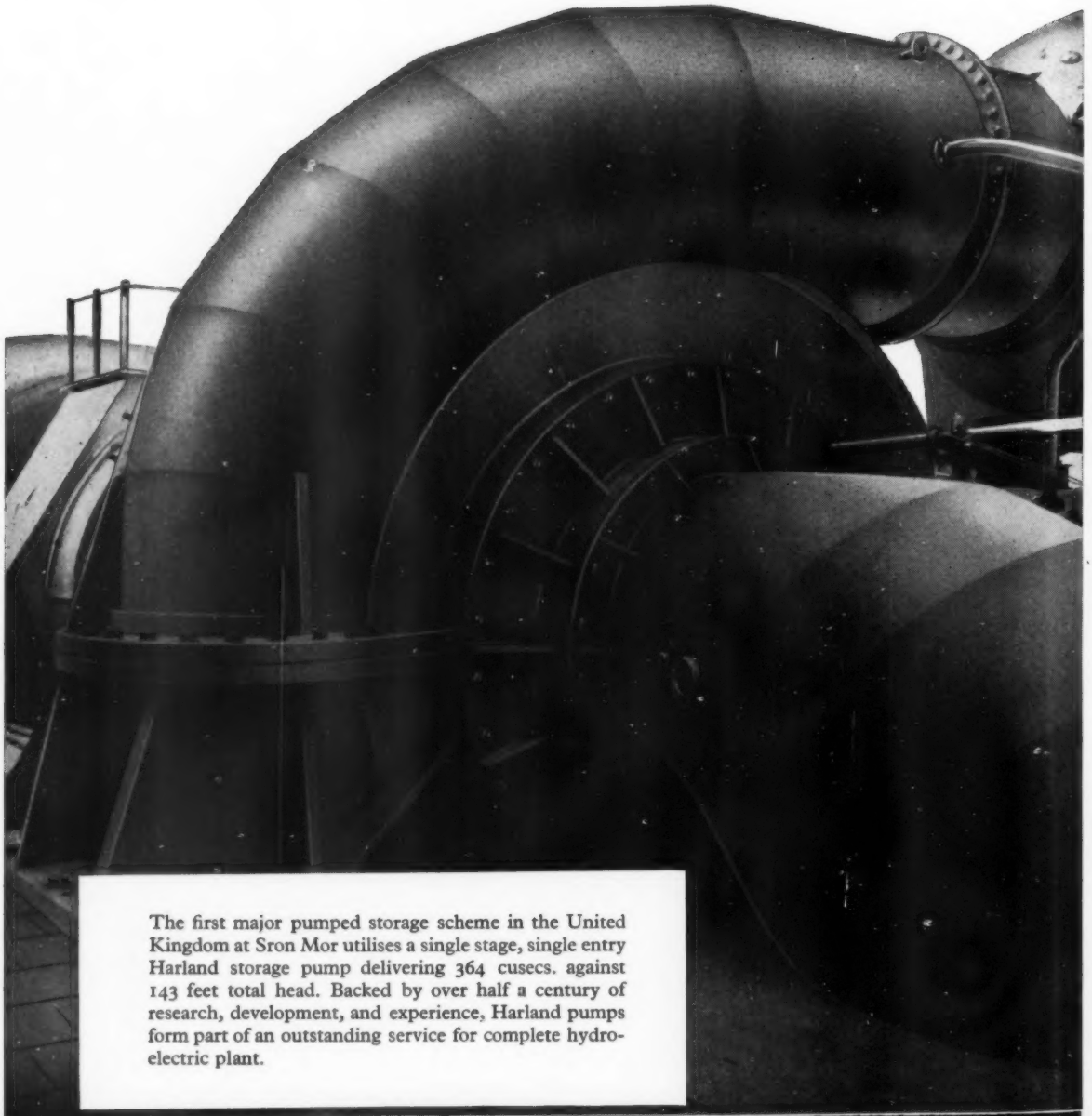

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A technical journal devoted to the study of all aspects of hydro-electric development

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New power for a Dominion from the Roxburgh Hydro-Electric Project

New Zealand's largest hydro-electrical undertaking, the Roxburgh project, will eventually feed an additional 320,000 kilowatts of electricity into the South Island grid system. The 1,200 ft. Dam, which is the largest ever built in the Dominion, was completed far ahead of schedule by Cubitts' New Zealand Co., in association with Conrad Zschokke Ltd., Geneva, and Downer & Co. Ltd., New Zealand.

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Economy of Hydro-Electric Power

OUR friends in the nuclear power world have been finding out, sometimes painfully, that there is more than one way to use nuclear power for the generation of electricity. Hydro-electric engineers have long been aware of the diversity of methods which may be employed to utilise the power in falling water.

In the light of the many designs of nuclear reactor, all of them costly, which have been canvassed in the last few years, it is of interest to draw some parallels in hydro-electric development. In France, for example, it has often been found that the most complicated type of thin-arch structure is often the least costly on a particular site, even if the actual costs on model tests, shuttering, and pouring are greater than those which might apply to a less involved design. The reason for this economy, of course, lies in the greatly reduced volume of raw materials that is needed.

In other parts of the world, engineers have to draw a fine distinction between the use of greater quantities of relatively inexpensive man-hours, where labour is cheap, and the use of certain construction methods including a high degree of mechanisation. Yet other methods have to be employed where skilled labour is scarce but, perhaps, materials are abundant and are found near to hand. For these latter designs, gravity type structures are often particularly suitable.

The nuclear engineers are fortunate in being able to draw on large amounts of Government money (in most cases) for large-scale experimentation with the reactor designs they produce; and although such matters are not mentioned at nuclear power conferences, there is always the military background to their efforts to be considered. Hydro-electric engineers, on the other hand, have to take their decisions with the aid only of model tests, and the funds at their disposal are strictly limited by commercial considerations. Once it has been decided to build a particular type of structure on a particular site, there is no turning back, and the "experiment" cannot be abandoned. If the geological studies were not sufficiently thorough, enormous sums of money may have to be found to prevent serious settlement or even leakage on a catastrophic scale from occurring; but unfortunately errors in design are so few as to be almost unheard of.

The development of nuclear power has taken place over a period of no more than about ten years, and great credit is due to those responsible for evolving at least a dozen types of workable reactor during that period. With the acclamation rightfully accorded to those who have made possible the production of power from nuclear energy, the focus of engineering attention has been somewhat turned away from the hydro-electric engineer. But his achievements, too, in a corresponding period are almost equally worthy of acclaim.

For example, there has been substantial reduction in capital cost due to the evolution of constructional equipment of the most highly mechanised type. Using, to mention a specific case, shuttering and scaffolding which can be rapidly erected, rapidly moved, and equally rapidly dismantled, has saved, in the aggregate, many millions of man-hours and a corresponding sum in money.

The actual materials used for hydro-electric construction have also been the subject of rapid improvement, again leading to economy. For example, on major construction sites the concrete-making plant is nowadays equipped to produce a constant flow of an exact mixture, evolved by exhaustive tests as being the most suitable for the work in hand. The increasing use of blast-furnace slag, under carefully controlled conditions, has led to the manufacture of concrete with very greatly increased resistance to

TO OUR READERS

We regret that because of a dispute in the British printing industry, to which we were not parties and which involved matters beyond our control, printing of this issue has been delayed. Publication of forthcoming issues will be expedited to compensate.

weather and the action of waves on the reservoir side. This, in turn, has led to reduced maintenance costs, leading to cheaper electricity. In addition, these improved concretes resist frost to a greater degree than ever before, and this again assists in keeping maintenance costs to a minimum.

In the broader field, experience has led to the development of economical means for harnessing the smaller water courses, which, up to a decade ago might well have been thought to be uneconomic for hydro-electric exploitation. The development of the submerged "bulb" types of unit which can be neatly tucked away in very small dams and can operate largely unattended from month to month, may well mean that a country's electricity supply system has added to it valuable aids to peak load working, with a corresponding advantage to all other type of plant on the system, thermal, nuclear and hydro.

The hydro-electric engineer in general has almost as many solutions to offer in the case of a particular power generation problem (providing always there is a fall of water to be harnessed) as the nuclear engineer; and it may well be that soil mechanics can provide still further solutions for dams where the site is of an unsatisfactory nature. In the case of the nuclear stations, the factor of obsolescence will undoubtedly intrude, so fast is the advance in nuclear science. Even if, in a particular situation, the hydro-electric engineer did not offer the most economic solution, nevertheless the plant he installs will continue for an unlimited period of time to function and contribute its quota of power.

It is high time that the public was made more aware of the part played by the hydro-electric engineer, behind the scenes, in ensuring a stable and permanent supply of the energy so greedily demanded.

Power Trends in Europe

ACHIEVEMENTS and forecasts over the period 1956–1963 are summarised in a publication "The Electricity Supply Industry in Europe" issued by the O.E.E.C. The slackening of economic activity in 1957 had little effect on power consumption, which increased by 6·5% during that year. It is expected that during the next five years the demand for electricity will go on increasing by about 7% per annum, and by 1963 from 10 to 12 nuclear stations, totalling 3,250 MW, should be in commission. Total power-station capacity rose from 102,442 MW in 1956 to 109,941 MW in 1957—an increase of 7·3%—and at this rate of increase the installed capacity in 1963 should reach 161,600 MW. The percentage accounted for by hydro plants will tend to fall slightly, to 35·8% in 1963 as compared with 37% in 1956.

Electricity production in 1957 for all member countries combined amounted to 410·6 TWh, of which 153·1 TWh was of hydro origin. Based on an annual increase of 7% the production in 1963 is expected to reach 618·0 TWh. Per capita consumption for Europe as a whole amounted to 1,414 kWh, and should rise to 2,042 kWh in 1963.

Power exchange between countries with interconnected networks showed a further development in 1957. Owing to adverse hydro conditions, the increase was mainly in the form of exports from countries relying on thermal production to those with mainly hydro plants. For instance, Germany sold more power to Austria (1,064 GWh compared with 407 GWh in 1956) and to Switzerland (954 GWh compared with 462 GWh) whereas her purchases from these two countries remained unchanged. Similarly, Italy had to increase imports from 271 GWh in 1956 to 577 GWh in 1957, and France had to reduce exports from 756 to 558 GWh.

The foregoing conclusions are based on the statistical tables which form the major part of the publication to which we have referred.

State Electricity Commission of Victoria

IN its thirty-ninth annual report for the year 1957–1958, the State Electricity Commission of Victoria shows that the steady rate of development of hydro-electric projects in the State was maintained and that the sale of electricity from all sources increased by 325 million kWh, or 8·4 per cent.

The Number 1 power station at the Kiewa hydro-electric project is in an advanced stage of construction. All six of the 16,000 kW turbo-generators for this station have now been delivered and the first power should be forthcoming in 1960–61. The Number 4 Kiewa development has been in partial service since April 1956 and, during the year under review, the concrete lining of the tunnel diverting water from the West Kiewa river to Number 4 power station was finished, thus completing this stage of the project.

Under an agreement with the State Rivers and Water Supply Commission, all water released for irrigation purposes from the enlarged Cairn Curran reservoir at Baringhup (Central Victoria) will be available for hydro-electric generation through a 2,000 kW turbo-generator to be installed by 1960.

Work is now proceeding on the Victorian section of a 330 kV transmission line from Dederang to the Murray river to link with the Snowy Mountains hydro-electric scheme; the New South Wales section has also been commenced and both links should be in operation by the summer of 1959. Equipment is being installed at the Dederang switching station to receive power from the Snowy Mountains into the Victorian 220 kV system.

Loan Negotiated for Koyna

THE World Bank has made a loan equivalent to $25 million to India for the Koyna hydro-electric power project in the State of Bombay. The project will have an initial capacity of 240 MW and most of the power from the new plant will be fed into the power system which supplies the Bombay-Poona area, where industrial growth has created a continuing need for more power.

The project is being constructed on the Koyna river about 130 miles south-east of Bombay. The Koyna river rises in the Western Ghats and flows eastwards toward the Bay of Bengal. The main features of the project are the construction of a dam on the Koyna and the diversion of the waters of the reservoir westward through the mountains to a power house about 40 miles from the Arabian Sea. The Bank loan will help to finance the first stage of this project consisting of the dam, the tunnel system, the underground power house and four 60 MW generators and associated

transmission facilities. The transmission system will bring power to the Bombay area and to several towns and communities in the Maharashtra region in the vicinity of Koyna. Successive stages in the Koyna development, to be phased to meet the expected increases in power demand, will increase generating capacity to 570 MW and provide water storage for irrigation.

The Koyna project is being executed by the Bombay State Government. Upon completion of construction, the project will be turned over to the Bombay State Electricity Board.

The total cost of the first stage of the Koyna project is estimated at the equivalent of $118 million. The Central Government of India will provide all the financing for the project through long-term loans to the Bombay State Government. The World Bank loan of $25 million included in these funds will cover most of the foreign exchange requirements. The World Bank loan is for a term of 25 years and bears interest of 5¾% including the 1% commission which is allocated to the Bank's Special Reserve. Amortisation will begin in May 1965.

Prototype Machine for the Rance

A PROTOTYPE machine for the Rance tidal scheme recently left the NEYRPIC works at Grenoble for installation in a lock at St. Malo for full-scale experiments. The prototype will develop 12,200 metric h.p. at 88 r.p.m. under a head of 5·5 m. and a discharge of 227 cu. m. per sec. It is a horizontal axial-flow unit with adjustable runner blades, designed to operate either as a pump or as a turbine with a flow in either direction. The machine, which was shipped by rail on a special wagon, weighs 90 tons; the runner measures 5·8 m. over the blades and weighs 4 tons.

Water Power Resources of Canada

THE Water Resources Branch, Department of Northern Affairs and National Resources, Canada, has issued its annual review of the water power resources of Canada and of their development to the end of 1958. Based upon the Branch's water power inventory, resources are summarized and such salient features as provincial distribution, current progress of construction, rate of development and industrial utilization are discussed briefly. The currently recorded water power resources of Canada are shown as totalling more than 46 million h.p. under conditions of low stream flow and over 66 million h.p. at average flow, the latter figure representing a feasible turbine installation of more than 87 million h.p.

During 1958, a maximum yearly record of 2,485,040 h.p. of new hydro-electric capacity was brought into operation, after making allowance for the dismantling of 6,360 h.p. of existing capacity. In addition, good progress was made in the construction of other new developments and additional projects were being planned or were under investigation. At the end of 1958, the total installed capacity of hydro-electric and hydraulic stations was increased to 22,379,626 h.p. indicating that only about one-quarter of Canada's hydro-electric potential has been developed. The installed capacity of water power plants in Canada now equals 1,295 h.p. per thousand of population; about 78 per cent. of the power is developed by utilities and the remainder by industry. The pulp and paper, and the mineral industries, are important consumers of energy produced from water power.

Turbines for Messaure

THE Swedish State Power Board have ordered two Francis turbines from Nydqvist & Holm AB (NOHAB) for their Messaure power station on the Lule River in North Sweden. Each turbine will have an output of 193,600 h.p. at 150 r.p.m. under a net head of 86 m., and both machines are scheduled to come into operation during the autumn of 1962. The order represents a value of 5,400,000 Swedish kroner.

The Rio Grande Dam

ACCORDING to the Mexican Banco Nacional de Comercio Exterior, the International Water and Boundaries Commission is to review the technical studies carried out by the Ministry of Hydraulic Resources for the construction of the Diablo dam on the U.S. frontier in order to allow the development of final plans to be submitted to the Governments of the U.S. and Mexico. According to Mexican experts, the dam will have the following characteristics: it will provide irrigation water for 250,000 hectares within Mexican territory; it will be located between Piedras Negras and Villa Acuña in the State of Coahuila; it should be of sufficient capacity to regulate a flow of 4,000 cu. m. per sec. in the Rio Grande, reducing the possibilities of floods on both banks of the river; and it will allow the generation of 40 MW of electric power, to be shared equally between Mexico and the U.S.

Dominican Republic Proposals Studied

THE first meeting of a judging committee on proposals submitted by Dominican and overseas firms for a big hydro-electric scheme on the River Nizao, Dominican Republic, was held in Ciudad Trujillo recently. The committee consists of representatives of the Departments of Public Works and Agriculture and the Dominican Electricity Corporation. The scheme will include the storage of 600 million cu. m. of water, provide increased water and irrigation facilities for the Ciudad Trujillo area, and have a generating capacity of 135 MW.

Lectures on Uplift in Dams

DR. SERGE LELIAVSKY, a valued contributor to this journal, gave a series of lectures during May at Imperial College, South Kensington, on "Uplift in Gravity Dams." Dr. Leliavsky's original work on this problem is well known, and his recent book on the subject, reviewed in our January issue, sets forth his conclusions in detail. In the first of his lectures he reviewed the various approaches to the phenomenon of uplift; in the second he developed the conception of the flow net as the basic mechanism of uplift, and described various tests devised to determine the uplift coefficient; in the final lecture he gave an account of his own investigations and the conclusions he had been able to draw from them, and described various structural procedures to reduce uplift in dams. These lectures will shortly be serialised in this journal.

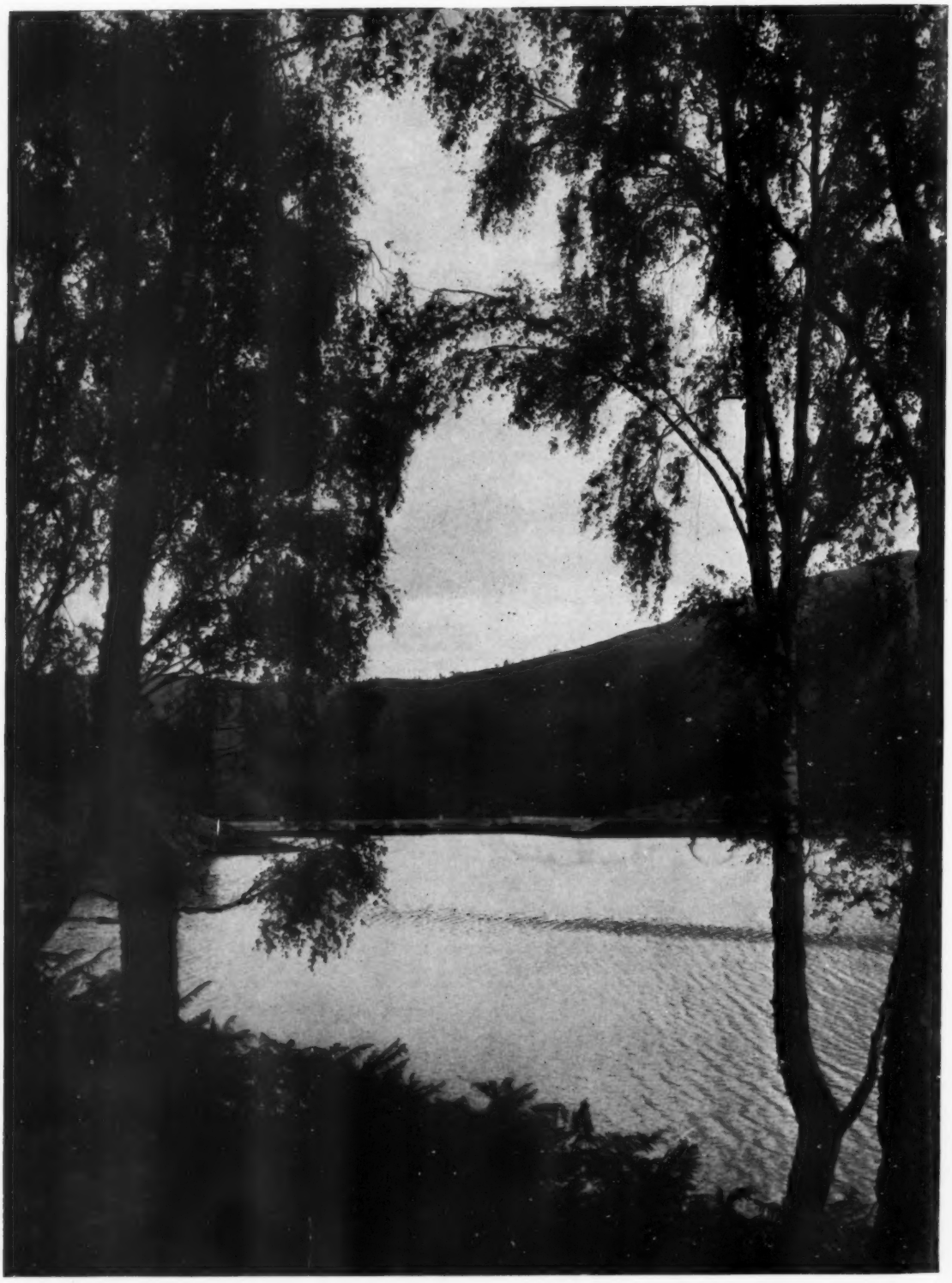


Fig. 11. The new Loch Dundreggan. In view of objections that are being raised on aesthetic grounds to hydro-electric development in Scotland, this picture is of special interest

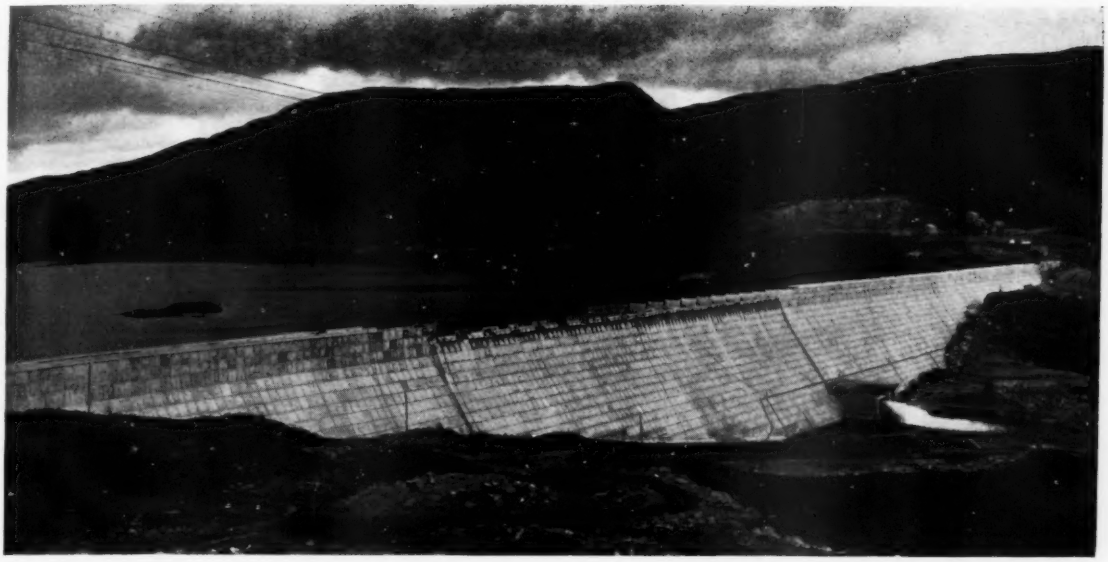


Fig. 12. Downstream view of Cluanie dam approaching completion

The Garry and Moriston Developments

A description of a co-ordinated hydro-electric scheme, in Glen Garry and Glen Moriston, Inverness-shire, in which some new civil-engineering techniques have been used for the first time in Britain

PART TWO

THE harnessing of the waters of the River Moriston and its tributaries was first proposed in 1928 but it was only twenty years later that the North of Scotland Hydro-Electric Board published a definite scheme, which was subsequently amended by altering the development in the lower glen from a two-stage to a single-stage project. One of the consequences of the scheme is the construction of a new trunk road 8 miles long and 18 ft. wide to link Glen Moriston with Glen Garry. Including the reconstruction of 11 miles of the Glen road, undertaken by the Government as part of their Crofter County Road Scheme, a further 22 miles of new or rebuilt main road in Glen Moriston have been completed since the Board embarked on this hydro-electric development.

Glen Moriston, in Inverness-shire, is one of the main west to east valleys terminating in the Great Glen. The hydro-electric scheme utilises the water-power resources of a 158 sq. mile catchment area for the annual production of about 216 million units of electricity. It comprises an upper and a lower section (Fig. 13), each with its own main power station, both stations being underground and representing excellent examples of this modern form of development.

The works of the upper section consist of two main dams, one at Loch Loyne and the other at Loch Cluanie. The Loyne dam is 1,745 ft. long and 58 ft. high and the total reservoir storage capacity is 1,520 million cu. ft. Water impounded in the loch, after passing through a 550 kW set, is discharged through a 7,600 ft. long, 12 ft. diameter horseshoe tunnel into Loch Cluanie.

The gravity dam at Cluanie is 2,220 ft. long and 128 ft. high; the water level has been raised by 96 ft. and the length of the loch has increased by about three miles to pass Cluanie Inn at the head of the glen. Cement was in short supply during construction of Loyne and Cluanie dams and Trief concrete was employed in each case, it being the first time that the process had been used in this country (see WATER POWER, December 1953).

Trief is a cementitious slag pioneered by M. Victor Trief, a Belgian. The process involves the replacement of a proportion of ordinary Portland cement in concrete by pozzolanas, in this case blast-furnace slag in vitreous form. M. Trief devised a method to increase the efficiency of grinding by using a wet mill to produce a slurry, which was mixed with the cement in the concrete mixer. Wet grinding produces a finer particle than dry grinding and reduces the power required; in addition, fine slags give better mechanical strength after hydration than do coarse ones and,

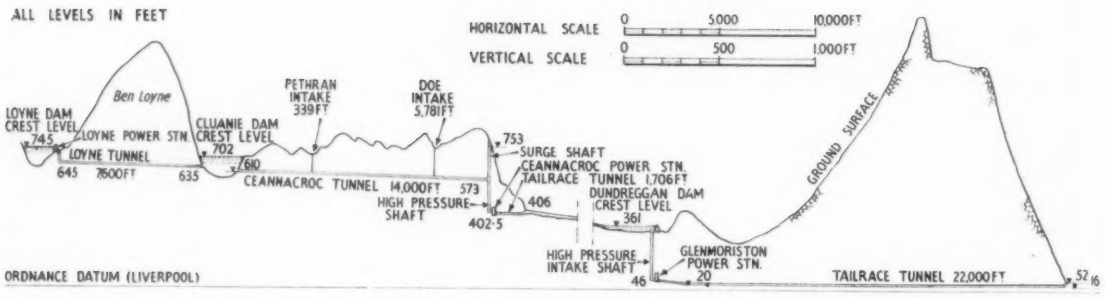


Fig. 13. Longitudinal section of Moriston scheme

after it is ground, the slurry can be kept in storage vats without deterioration providing it is agitated continuously to prevent settlement. Most of the slag used at Cluanie and Loyne dams was brought by road from steel mills in Lanarkshire to a wet-grinding mill and batching plant erected near Cluanie, where the bulk of the concrete for both dams and for much of the other civil-engineering work was mixed. A granite quarry was also opened near the batching plant and equipment was installed to give a maximum output of 200 tons per hour. Conveyor belts were set up to carry aggregate from the quarry to storage bins at the concrete plant and two overhead cableways at Cluanie, controlled by portable radio transmitters, linked the dam with the plant.

Three different main types of facing block were used for Cluanie and Loyne dams. All the units were designed for adjustment by concrete joggle blocks, acting as hinges and housed in recesses at the top and bottom edges. The weight of each block was governed by the capacity of the largest mobile crane that could be transported by the cableway and operate between the two faces at the top of Cluanie dam. The units, made of Portland cement, were cast on a vibrating table which was set up in the blockmaking shed adjacent to the batching plant near the dam and connected to it by cableways. Blocks for use at Loyne dam were transported to the site by road and derricks were used to place them in position.

The Ceannacroc tunnel is 14,000 ft. long and leads from Cluanie dam to the main power station of the upper Moriston development at Ceannacroc. The crest level at Cluanie dam is 702 ft. and the tunnel intake is at 610 ft. O.D. Two subsidiary sidestream intakes, one at Peathrain and the other at Doe, pass water through small tunnels to the main tunnel before it enters the vertical surge shaft at an elevation of 573 ft. O.D. The surge shaft is approximately 300 ft. high and is excavated out of the hillside.

Ceannacroc Power Station

This most attractive power station was the first major underground station to be built in this country. Access to it is through a 620 ft. tunnel of 18 ft. diameter, descending at a gradient of 1 in 9. This tunnel has been blasted through the hillside and it is now possible to see a complete cross-section of the various rock strata traversed at different levels. Although the roof of the power station has been lined with concrete, the walls are of natural rock and this has greatly enhanced the architectural beauty of the station. The lighting has been very carefully designed, and clear shadowless illumination has been achieved by locating the lights behind the overhead concrete beams which support the crane rails. The contrast between the darkness of the approach tunnel and the brilliance inside the power station is most effective.

The power stations at Ceannacroc and Glenmoriston have comparable heads but differing flows and, at the former, the compensation flow required demanded a 4 MW unit; at Glenmoriston, limited storage space made two units preferable to one. Total capacities required for the two stations were 20 MW and 36 MW respectively and it was therefore decided to install three similar machines, one for Ceannacroc to be installed alongside a 4 MW unit, and the remaining two, rated at 18 MW each, for Glenmoriston. The conditions governing speed and pressure regulation at both stations made relief valves unnecessary and it was thus possible to order similar machines although the turbine housings at Glenmoriston had to be reinforced to withstand tailrace surge pressures.

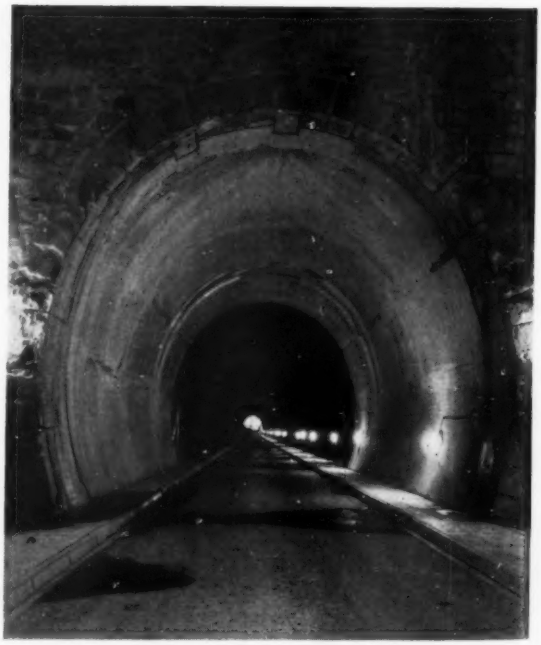


Fig. 14. Entrance to Ceannacroc station

Fig. 15. View of Ceannacroc power station from the loading bay

The entrance to the two-floor Ceannacroc station is at the generator floor level, which houses the machine control boards, the turbine control panels and the governors. The turbine floor is some 10 ft. below this level, and includes the inlet-valve pit. The 16 MW units at Ceannacroc and Glenmoriston were supplied by the English Electric Co. Ltd. At Ceannacroc, the English Electric turbine is placed nearest to the loading bay, while the governor actuator and servomotor, and the governor oil pumping set are on the upper floor near the generator. The oil pumping set for the generator bearings is on the lower floor between the units and the bearing oil cooler is located in the straight-flow valve pit.

The turbine spiral casing is constructed of electrically welded mild-steel plate, has a logarithmic spiral form and is generally circular in cross section. The fabricated speed ring, which forms an integral part of the spiral assembly, is designed to bridge the throat of the casing and to act as a channel for the guide vanes. The ten stay vanes help to transmit the weight of the alternator to the foundations.

The stainless clad fabricated runner is of normal Francis design, with integrally machined labyrinth seals on the runner crown and skirt. The self-lubricating turbine bearing comprises a support in halves with a heavy joint and flanges. Pads for the bearings are bolted and dowelled to the support ring and are lined with whitemetal carrying grooves and intakes; oil is sucked up by each pad and then overflows back into the main sump.

Movement of the straight-flow valve door is controlled by a servomotor piston operating under pipeline water pressure. When closed, the valve is normally sealed on the downstream face of the plug by a service seal which operates automatically. A manually operated isolating seal, sealing the upstream face of the valve plug, is provided for maintenance and inspection. The valve is normally opened only when the water pressure on both upstream and downstream sides is balanced but it will also close under unbalanced conditions.

The turbine inlet for the 4 MW unit is fitted with a 42 in. diameter Harland-Morgan Smith Rotovalve. This full-bore, plug-type valve presents no obstruction to the water discharge when fully opened and the friction loss is equivalent to that of a pipe of equal length and diameter. A hydraulically operated servomotor is provided to control this valve which can also be opened or closed manually, when the penstock is empty, by a hand pump provided for this purpose. The vertical-shaft single-runner Harland-Morgan Smith Francis turbine is designed to produce 5,600 b.h.p. under a head of 254 ft. at 500 r.p.m. Where possible, fabricated construction has been used throughout and the stainless-steel runner is bolted to the forged shaft. A segmental carbon-ring shaft gland is provided. The self-lubricating pivoted-pad shaft bearing is fitted with internal cooling coils supplied from the penstock through a strainer and pressure reducing valve.

The automatic oil pressure governor is operated by a servomotor and is sensitive to speed variations of 0·25%. The load-limiting device is also motor oper-

ated, enabling load-limit settings to be made remotely. Selsyn transmitters and receivers are fitted on the governor and machine control board respectively to allow the load-limit setting and gate opening to be compared.

The vertical shaft synchronous generator is coupled to and driven by the turbine; it is rated at 4,700 kVA at 0·85 p.f. lagging and run at 500 r.p.m. The first of the two pivoted-pad bearings is mounted on the bottom bracket below the salient-pole rotor and the combined thrust and guide bearing above the rotor is carried on the top bracket.

The discharge flows from the two machines at Ceannacroc join just downstream of the draft tubes and pass through a free flowing tailrace tunnel approximately 1,700 ft. long. This tunnel has a concrete lined invert but the remainder is unlined apart from a section at the draft tube junction and another at the portal. The tunnel discharges into an open channel from which the water is passed back into the River Moriston through screens on the line of the river bank. These screens are to prevent fish from being attracted into the tunnel and to encourage them to swim up the river towards the fish heck.

Dundreggan dam

About 10 miles downstream of the Ceannacroc tailrace the Dundreggan dam has been constructed to form a balancing reservoir or headpond for the second stage. This is a gravity dam 55 ft. high and adjacent to it is the intake into a vertical shaft leading to the power station.

The water level in Loch Dundreggan is controlled by radial gates and this is one of the first times that such gates have been used for this purpose on a dam in the Scottish highlands. They are automatically controlled in conjunction with the level of water in the reservoir. A small vertical propeller compensation set is installed in the dam; this set has a capacity of 165 kW and operates at 1,020 r.p.m. under a design head of 42·5 ft.

The water level at the dam has to be kept to the minimum in order to protect agricultural land, which is at a premium in the area. The maximum catastrophic flood discharge through the gates is estimated at 30,000 cusecs and artificial spates of 370 cusecs must be passed as part of the compensation-water requirement; in addition, provision has had to be made to pass the full turbine discharge if the load should be rejected. A further necessity was for one of the gates to dip below the surface in order to pass floating debris while the others had to lift clear of the surface to allow the passage of flood-borne matter in suspension. A series of model tests was carried out to find the best solution and the installation adopted was two 28½ ft. × 27 ft. radial gates and one 20 ft. × 10 ft. tilting gate. All the gates are electrically operated, powered from an independent battery circuit, but an emergency manual control is also available for use in the event of electrical failure. Each gate is equipped with a pushbutton board, and remote water-level and gate-position indicators are provided in the generating station. The radial gates are of conventional welded design. The tilting gate is of riveted construction and since it provides a more sensitive control of the discharge it opens first in the automatic control sequence and the larger, radial, gates are not brought into operation except in major floods.

The catchment area for the Dundreggan dam is 155·1 sq. miles with an average annual rainfall of 81·1 in. and an average annual run-off of 68·1 in. Spillage and compensation losses are about 140 cusecs and the average flow available for power production is 642 cusecs. This concrete gravity dam is 55 ft. high, 400 ft. long and has a total volume of 35,000 cu. yd.

Glenmoriston Power Station

Three hundred feet below Dundreggan dam is the second main power station of the Moriston development. In fact, this power station is the main unit of the lower stage and is the largest in the entire Garry and Moriston schemes.

Many problems arose in building the underground station at Glenmoriston. The rock in this region consists of psammitic and pelitic schists with many injections of igneous rocks. Although at Ceannacroc the cores showed undisturbed rock, at Glenmoriston there was complex jointing and some shattering, so that further geological investigation was necessary. A shaft was sunk along the line of the proposed intake and from it a gallery was driven to enter and traverse the site of the future station. These operations proved that the initial survey was correct but the rock was nevertheless considered stable enough to carry out

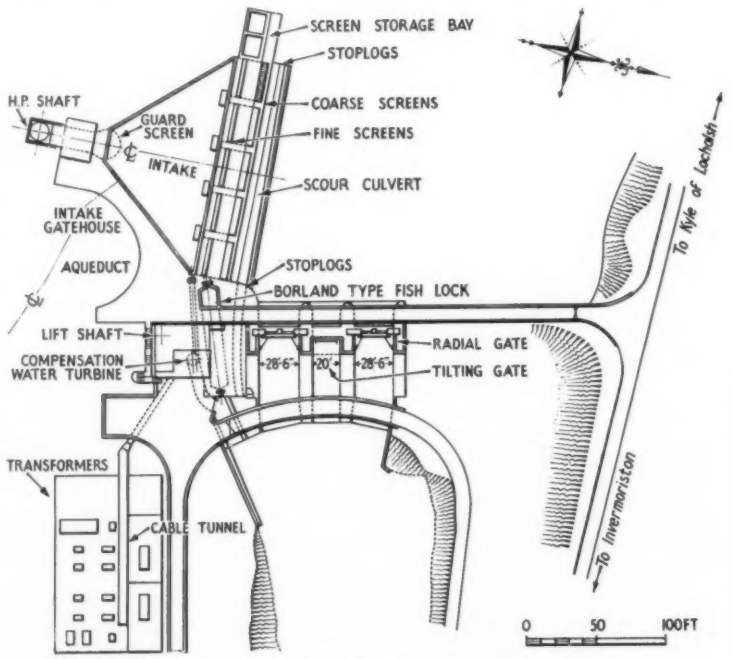


Fig. 16. Layout and details of Dundreggan dam

Fig. 17. Dundreggan dam and fish pass seen from downstream

the excavations required. Excavation of the power station began at the level of the access tunnel, approximately 40 ft. below the roof. An inclined tunnel of 1 in 6 gradient was driven from this level across the station to a point approximately 20 ft. below the roof. The whole roof of the station was then excavated to simplify concreting of the arch and to enable a rail-mounted travelling shutter to be used. As soon as this work was completed, the station was excavated to the 62 ft. O.D. level throughout. While this work was going on, two draft tubes had been driven from the surge shaft; when the 62 ft. level in the power station was reached, pilot holes were sunk into the draft tubes and mucking out between the 62 ft. and 28 ft. levels was completed through these holes. A Caterpillar shovel, working in conjunction with an Eimco loader, was used to load the muck onto a fleet of Dodge lorries.

The arched roof of the power station was concreted and then grouted with sand and cement under pressure. As already mentioned, the quality of the rock at Glenmoriston is inferior to that found at Ceannacroc and, during excavation, the inflow of ground water was about 50,000 g.p.h. The walls were strengthened by 9 ft. Perfo rock bolts at 4 ft. centres and a concrete facing was applied prior to grouting in three stages, during which pressure-relief holes were provided through the concrete facings.

The access tunnel is 2,200 ft. long with a gradient of 1 in 12. It has an equivalent width of 17 ft. 4 in. and a height of 5 ft. 8 in., and was driven with Atlas Copco drills and pusher legs mounted on a jumbo specially designed on the site and made by Duncan Logan (Plant) Ltd.

The tailrace tunnel has an overall length of 21,800 ft. with an equivalent diameter of 20 ft. 9 in. About one mile from the dam, a 1,300 ft. long adit was made so that the tunnel could be driven from two headings. Some interesting innovations were used to drive the tailrace tunnel and the adit, and will now be described.

At the outfall of the tailrace, the original jumbo had two platforms. When the lower platform was not in use, it was raised by pulley blocks driven by compressed air. All the jumbos were fitted with tyred wheels for easy removal from the rock face during the blasting and mucking cycle. Modified Fordson tractors with a capacity of 9 cu. yd. were used at the tailrace; although the engine, gearbox and rear transmission were left unaltered, the driver's seat, the steering mechanism and the brakes were moved upwards to a position above, but only slightly behind, the nearside front wheel. The rear wheels were reinforced and, over the back axle, a heavy pivot base was placed to provide a seating for the very robust carrier body.

An unusual feature of the civil-engineering work at the Lower Moriston development was the use of rubber-tyred transport and conveyor belts for mucking out. Contrary to common tunnelling practice, no rail-track vehicles were used and, since this was the first occasion on which major underground power stations had been built in the country, much of the equipment was adapted or developed as the work progressed and the need arose. Many of the methods applied were those commonly used in Scandinavia, and extensive study was carried out by all the civil-engineering contractors to ensure that the maximum possible benefit was obtained from past experience abroad.

The two English Electric vertical Francis turbines are of very similar design to the 16 MW unit installed at Ceannacroc. The design head at Glenmoriston is 285 ft. and the average gross head is 310·5 ft.; annual load factor is 41% and the flow at rated capacity and mean head is 1,720 cusecs. Both turbines operate at 375 r.p.m. and each has a capacity of 25,000 b.h.p.; speed and pressure rises for load rejection are 19·0% and 18·0% respectively.

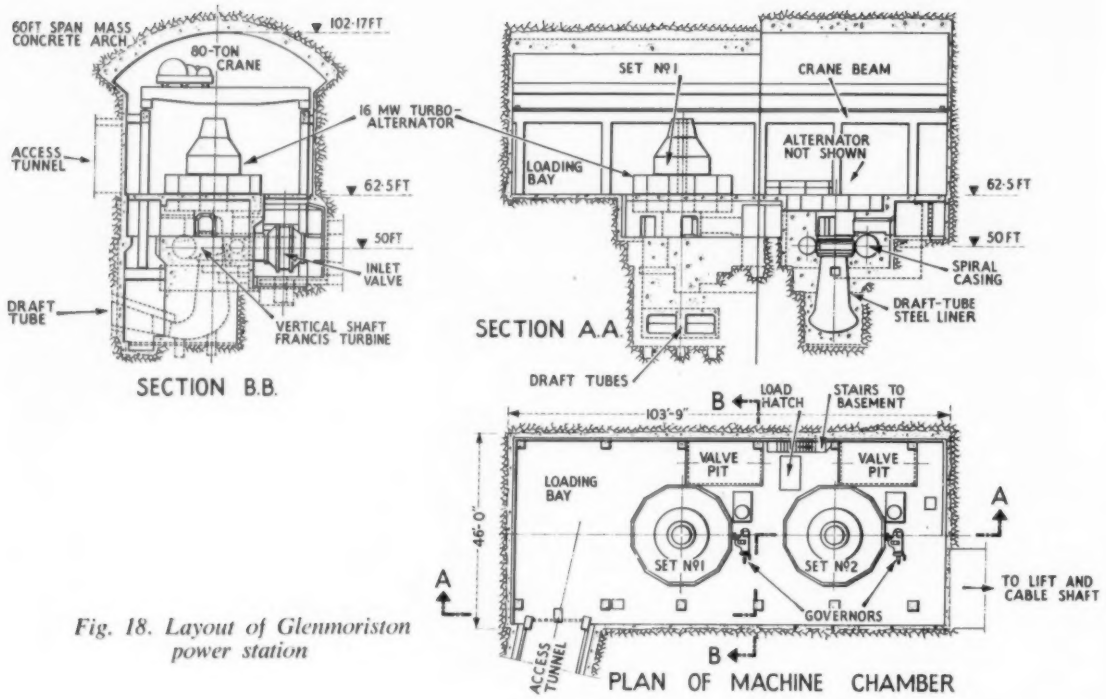


Fig. 18. Layout of Glenmoriston power station

The spiral casing has an inlet diameter of 6 ft. 4 in. and is made of electrically welded mild-steel plate graduated in thickness to suit the pressure. Both inlet valves are of the straight-flow type, hydraulically operated and with a bore of 6 ft. 4 in.

The generators, also supplied by English Electric, are two-bracket units, with the upper bracket carrying the pivoted-pad thrust and upper guide bearings while the lower bracket supports the lower guide bearing and the brakes. All the bearings are lubricated with oil pumped from a separate set with main and standby pumps and oil coolers. Closed circuit air cooling is also provided.

Automatic voltage control is maintained by two magnetic amplifier voltage regulators and exciter field rheostats. The lubrication systems for the turbines and alternators are entirely independent; duplicate a.c. motor pumps are provided for the alternator bearings and oil pressure for the governor is maintained by an electrically driven pump delivering into a receiver through an unloader valve. There are two standby governor pumping sets and other pumps are supplied for power station dewatering and drainage; the dewatering pumps operate under floatless water level control and deal with seepage and drain water from other sources. The station first started operating in 1957 and was officially opened on 27 September 1958.

Before leaving this stage of the development, it may be interesting to compare the assembly bay areas at Ceannacroc and Glenmoriston power stations, namely 1,140 sq. ft. and 890 sq. ft. respectively, a remarkable difference in view of the fact that the capacity of the latter station is 16 MW higher than the former. In both cases, the alternators emerge partly above floor level and contiguous with the assembly bay, while the access to the turbines and inlet valves is from below. Overhead cranes of 80 tons capacity are installed in each case but the spans are 41·5 ft. at Ceannacroc and 38 ft. at Glenmoriston.

Fish Protection

An interesting aspect of the whole Moriston development is the care which has been taken to safeguard the normal propagation of the salmon. When Cluanie dam was built, the resultant diversion of water made it necessary to construct a weir and traps to prevent the fish ascending into the upper rivers during the construction period and to trap and hold them at that time and later.

The River Moriston has an annual run of salmon, the upstream migration starting in May and continuing throughout the summer. Before the hydro-electric development began the fish spawned in the river above and just below Loch Cluanie and above Loch Loyne. Owing to the construction of the Cluanie and Loyne dams, salmon are now unable to reach their natural spawning grounds. The greater part of the weir at Ceannacroc bridge consists of a spillway, but at the north end the fish can enter a trap and are led direct into enclosures where they are held until ripe for stripping in the late autumn. The eggs taken from the females and fertilised by milt from the males are taken to the Invergarry hatchery where they are incubated during the winter months. The resulting fry are planted in the Moriston below the Cluanie dam in the spring.

Between the downstream ends of these walls are two curved screens separated by a 7 in. gap and forming a bellmouth entry into the salmon trap. By lowering the stop-logs and increasing the flow between the walls and through the screens, the salmon are drawn towards the bellmouth opening and thus find

Fig. 19. Glenmoriston station, showing the two 16 MW sets

their way through the 7 in. gap. Inside the trap, the fish are caught and their eggs or spawn milked into containers which are then taken to a special hatchery at Invergarry.

A Borland Fishpass is included in the structure of Dundreggan dam, below which the Moriston river is comparatively wide and, in many places, both irregular and extremely shallow. In order to facilitate the passage of salmon during low flows gabions have been used for partial river closure, thus forming narrow channels through which the discharge is deeper. Only some years of experience will show whether this is a satisfactory permanent solution but, at this stage, it is worth noting that the gabions have enhanced rather than impaired the great scenic beauty of the lower glen.

Despite the presence of dams, tunnels, and all the ancillary buildings and equipment that accompany any hydro-electric development, Glen Moriston is still the beautiful valley that it always has been; construction has been designed to blend with nature and the result is an attractive compromise.

Electrical System

As already mentioned, the group control centre for the combined Garry and Moriston developments is at Auchterawe switching station, Fort Augustus, the main power stations being connected to this switching station by 132 kV lines. In addition, this switching station provides a main switching point for a number of 132 kV lines which radiate south to Fort William, north to Fasnakyle and Beauly, and east to Errochty and Aberdeen via the Corrieyairack Pass.

The switching station is equipped with 132 kV, 600 amp, 2,500 MVA, small oil volume, air-operated outdoor switchgear. The 132 kV lines to Fasnakyle, Beauly, Errochty and Aberdeen are provided with carrier current protection and phase-phase carrier communication equipment which connects the station to the North of Scotland Hydro-Electric Board's

Fig. 20. The fish heck at Loch Poulary

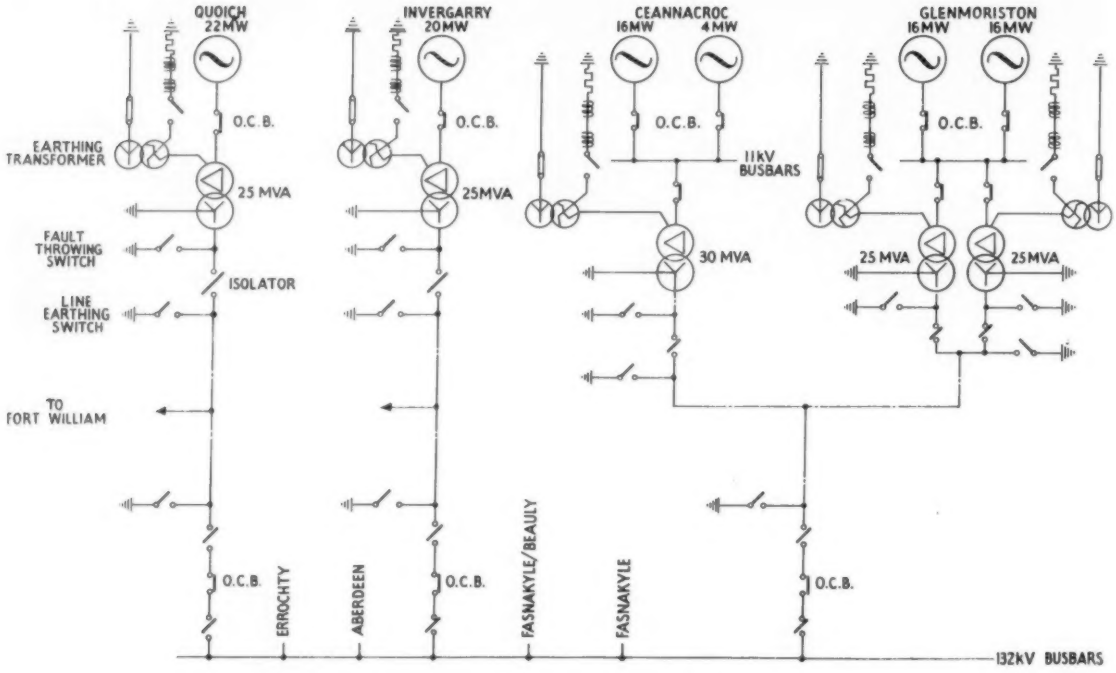


Fig. 21. Main connections with Fort Augustus group control centre

general power line carrier communication system.

The control centre is provided with miniature direct-wire control equipment for the 132 kV switchgear and is designed for the subsequent addition, as and when required, of full remote control of the power stations in both valleys. At present only general alarms are brought back from the power stations, plus indication of megawatts and megavars for the individual machines.

Communication between the control centre and the main power stations is provided by power line carrier equipment, using one of the 132 kV conductors and earth return. Voice frequency telegraph circuits, superimposed over this carrier system, are used for the transmission of the general alarms and meter readings referred to earlier. Extensions from this communication system are taken over pilot wires to the headworks and to small compensation stations which have been established.

Acknowledgments

We are happy to record our indebtedness to the North of Scotland Hydro-Electric Board for their kind permission to publish these articles and we should like to acknowledge the courtesy of the many members of the Board's staff who assisted us during our visit. We have also derived much invaluable information from a paper entitled "The Garry and Moriston Hydro-Electric Schemes," by Messrs. C. M. Roberts, E. B. Wilson, J. H. Thornton and H. Headland, read before The Institution of Civil Engineers, London, on 14 October 1958.

List of Consultants and Contractors

CONSULTING ENGINEERS

Civil	Sir William Halcrow and Partners
Mechanical and electrical	Kennedy & Donkin

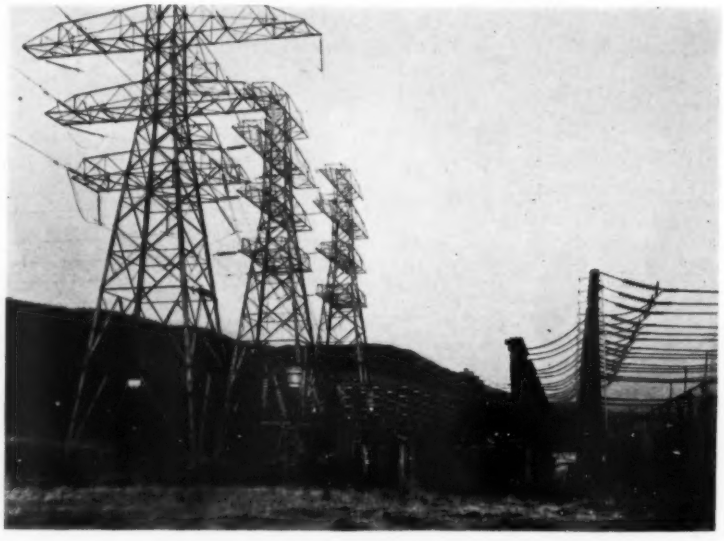


Fig. 22. Switching station at Fort Augustus

ARCHITECTS

Garry works	Gratton and McLean
Moriston works	Robert Hurd, Esq.

CIVIL ENGINEERING CONTRACTORS—GARRY PROJECT

Borings	Soil Mechanics Ltd.
Quoich dam and tunnel Quoich fish heck Quoich generating station Coire Shubh Beag aqueduct	Richard Costain Ltd. (Aqueduct sub-let to P. J. L. Heron Ltd.)
Invergarry dam Invergarry road diversion Invergarry tunnel Invergarry generation station C.E. works and superstructure Smolt rearing ponds and Emergency water supplies	Whatlings Ltd. (Road diversion sub-let to Kings & Co.)
Glen Quoich road bridge	Sir William Arrol & Co. Ltd.
Fish traps at Quoich fish heck Additions to Invergarry hatchery Access road from Quoich generating station to fish heck Fish trap on Aldernaig Burn Emergency repairs to Invergarry road diversion and Protection works	P. L. J. Heron Ltd.
Demolition of buildings Additional water supplies and other improvements at Invergarry Fish hatchery	Construction & Engineering Co. Ltd.
Head-loss equipment at Invergarry tunnel intake	Evershed & Vignoles Ltd.
Work at Quoich fish tank and Generating station tailrace	Alex. Robertson & Co.
Compensation water recorder house	Alex. Fraser
Quoich gatehouse repairs Compensation water by-pass Quoich dam Alterations at Invergarry Compensation water generating station	Duncan Logan (Builders) Ltd.
Deepening of Quoich fish holding ponds Quoich dam parapet walls Stoplog needle storage tank Camp site restoration	A. A. Stuart & Sons (Glasgow) Ltd.
Paths and surfacing	Kings & Co.
Invergarry generating station (Drainage improvements)	Duncan Logan (Contractors) Ltd.
Waterproofing of compensation water generating station walls	Sika Ltd.

CIVIL ENGINEERING CONTRACTORS—MORISTON PROJECT

Borings	Le Grand Sutcliffe & Gell.
River flow gauging works Erection of fish watcher's hut	Alex. Fraser
Loyne dam and tunnel Cluanie dam Ceannacroc tunnel and power station Dundreggan high-pressure shaft	Mitchell Construction Co.
Cluanie and Dundreggan road diversions	International Development Co.
Borings at Ceannacroc and Glenmoriston power stations	Cementation Co.
Lower Moriston works	Duncan Logan (Contractors) Ltd.
Salmon storage pool at Ceannacroc Allt Garbh Dhoire aqueduct Reinstatement of road works	P. L. J. Heron Ltd.
Ceannacroc tunnel, adit drainage	A. A. Stuart & Sons

MORISTON EXTENSIONS

Garry Moriston road	Farrans Ltd.
Cluanie West road diversion	W. J. Anderson Ltd.

Principal Mechanical and Electrical Contractors

Station	*Turbine contractor*	*Generator contractor*
Quoich	Boving & Co. Ltd.	English Electric Co. Ltd.
Quoich (compensation water station)	Gilbert Gilkes & Gordon Ltd.	Bruce Peebles & Co. Ltd.
Invergarry	English Electric Co. Ltd.	
Invergarry (compensation water station)	The Armfield Hydraulic Engineering Co. Ltd.	Bruce Peebles & Co. Ltd.
Loyne	Boving & Co. Ltd.	English Electric Co. Ltd.
Cluanie (compensation water station)	The Armfield Hydraulic Engineering Co. Ltd.	Bruce Peebles & Co. Ltd.
Ceannacroc 4 MW 16 MW	The Harland Engineering Co. Ltd. English Electric Co. Ltd.	
Dundreggan (compensation water station)	Boving & Co. Ltd.	Bruce Peebles & Co. Ltd.
Glen Moriston	English Electric Co. Ltd.	

Copper Cables. A 62-page booklet from the Copper Development Association, 55 South Audley Street, London, W.1, entitled "Copper Cables," gives an admirable survey of the many types of insulated cables available, chiefly for the benefit of those outside the cable-making industry. After discussing the properties of copper and some copper alloys and the manufacture of copper wire, the booklet deals in turn with power cables, telephone cables, and miscellaneous cables. An appendix gives formulae for the main electrical characteristics of cables. Pretty well all types of insulated cable in use at the present time are described, and the text is embellished by numerous illustrations.

"Secoflex" is the name of a new expansion joint sealing material introduced by Secomastic Limited. It is claimed to have excellent adhesive properties, and, being flexible at all times, to be very suitable for joints in reservoirs, aqueducts and steel-framed structures.

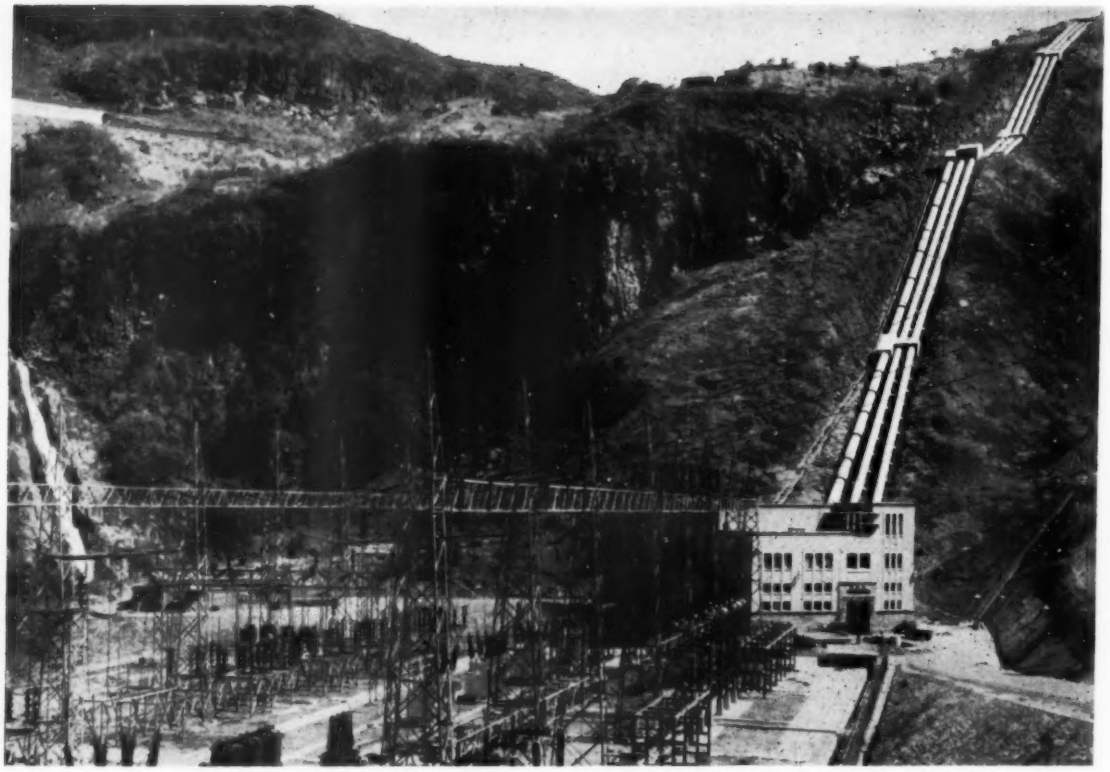


Fig. 1. Ixtapantongo station, containing one 45 MW and two 28 MW sets operating under a head of 328 m.

Mexico's Power Development

An outline is given of the state of hydro-electric development in Mexico, with special reference to the work of the Comision Federal De Electricidad. A brief sketch is given of the Mazatepec scheme

By P. J. BIER, Consulting Engineer

THE Federal Government of Mexico is making strenuous efforts to develop the power resources of the country as quickly as finances permit. There is a growing power demand and already over a hundred power plants, steam, diesel, and hydro-electric, have been built and are in operation. One of the most interesting hydro-electric plants completed recently is the underground power plant at Tingambato on the Rio Tilostoc, located south-west of Mexico city, in the state of Michoacan, which has an installed capacity of 135,000 kW. A number of other hydro-electric plants such as Temaxcal, El Fuerte, Cupatitzio, Mazatepec, etc. are at present under construction, while others are in the planning stage. Two of the plants completed several years ago are shown in the accompanying photographs. Fig. 1 shows the Ixtapantongo power plant, which has a static head of 1,075 ft. and an installed capacity of 106,000 kW. Fig. 2 shows the Santa Barbara power plant, which has a static head of 860 ft. and an installed capacity of 67,500 kW. Both plants are located south-west of Mexico city, in the vicinity of the Tingambato plant.

Much of the power-development work of the Federal Government, especially portions calling for expenditures in foreign countries for equipment not available in Mexico, is being financed by the International Bank for Reconstruction and Development, commonly referred to as the World Bank. Assistance of this kind by the World Bank is a boon to under-developed countries as it gives them an opportunity to help themselves in developing their own resources and thus raise the living standards of their peoples.

Under the terms of the World Bank loans the funds

advanced must be spent on projects which are economically feasible, thus assuring repayment of the loan with interest within the specified time. To assure compliance with this rule the Bank sends out investigators, principally engineers, to review the cost estimates of the projects, their economic feasibility, and the borrower's ability to carry out the work and repay the loan. This inspection is also maintained during construction to check whether the field work is done as efficiently as expected to keep the costs within the engineering estimates.

The World Bank, among other things, also requires that the materials and equipment for the construction work be purchased on the basis of competitive bidding without restriction as to the source of the bids, as long as they meet the requirements of the specifications on which the contract is based. This naturally leads to bidding on an international basis with the result that contracts for materials and machinery not available in Mexico are awarded to manufacturers in foreign countries. Manufacturers in England, Germany, France, Switzerland and Italy are, due to their lower costs, generally in a position to underbid American companies and obtain most of the contracts. Recently Japanese companies of power equipment also joined the rank of bidders and are consistently underbidding not only American but also European manufacturers.

The general engineering work for the above power development is performed by a federal agency called the Comision Federal De Electricidad (Federal Electric Commission) which is headed by an electrical engineer of prominence, Sr. Carlos Ramirez Ulloa[1], as Director General. The general offices of the Commission are located in an imposing building in Mexico city, which is the focal point of all activities in connection with the planning, design, construction, operation, and maintenance of power projects. A trained staff of engineers handles this work under the capable direction of the Chief engineer, Sr. Cesar Jimenez Lopez[2], and assistants. Each project office has, during the period of construction, a small staff of engineers and surveyors, stationed at the site of construction, which is under the supervision of the project engineer. The organisation is similar to that used by the Bureau of Reclamation and the U.S. Engineers in their construction activities. Some specialised technical and construction assistance is provided by American engineers engaged by the Commission as consultants and by others engaged as inspectors in welding, painting, grouting, etc. In general the Commission is following the time-tested rules and practices developed by the Bureau of Reclamation, which during its 56 years of existence after its founding in 1902 has acquired a great deal of valuable experience in this field. As a result, its rules and practices in irrigation and hydro-electric power development are generally followed where such work is taking place.

Due to the mountainous nature of Mexico only about 8% of the land area is suitable for agricultural development. The use of water resources for irrigational purposes is consequently of the utmost importance. This phase of the development work is carried out by another Government agency, the Recursos Hidraulicos (Hydraulic Resources Commission). The scarcity of tillable farming land is emphasised by the fact that in some areas even the mountain tops are cultivated, as can be observed when flying over the mountains. There is a very great variation of precipitation over the country; it may be only a few inches per annum in some areas and reach 200 in. or more in others. This results in either near-desert conditions or an excess of moisture, a fact which accounts for the great diversity of plant life in Mexico.

Engineering supervision of hydro-electric construction in Mexico calls for considerable travel, generally by plane, from the Commission's headquarters in Mexico city to the projects under construction, which are scattered over a large area of the country where water resources are available for power production. The Commission is quite efficient in facilitating travel to the projects by maintaining several planes for that purpose. Mexico is no small country and the distances to the various projects are too great to be covered in the desired time unless air travel is used. Consequently this mode of travel is favoured where landing strips are available within a reasonable distance from the project to be visited.

In a recent field trip to the Mazatepec hydro-electric project now under construction in a remote part to north-east of Mexico city, travel by automobile was necessary as a plane trip had to be ruled out owing to the lack of a suitably located landing field. A station wagon was used for the greater portion of the trip and was made on a well-paved main highway; we then changed to a construction road serving the project and the trip had to be continued on a jeep which, apart from a truck, was about the only means of travel capable of negotiating this narrow, steep and crooked road on which a speed of about 20 miles per hour could not be exceeded. It took about an hour to make the short trip of about 15 miles to project headquarters. The Commission uses special drivers on these field trips who know the road intimately and this reduces the possibility of accidents. A portion of this construction road follows the rim of a very steep canyon through which, hundreds of feet below, the Apulco river winds its course. Here there is a spectacular view in the form of a high waterfall followed by a small fall further downstream. Our destination, the construction camp, is in an extremely rugged area with scarcely a square foot of level surface except where excavated for construction. Practically every building is at a different elevation and the connecting roads are steep and narrow. The buildings are of concrete or masonry and have corrugated asbestos roofing. They consist of living quarters for the employees and families, an office building, dormitory, restaurant, etc., such as one usually finds in camps remote from towns. The hills around the camp are covered with banana trees, coffee plants and patches of corn scattered over the steep slopes. The site of the Apulco dam is a few miles away from the camp. Exploratory work was under way to determine the quality of the rock at the site by excavating test pits and tunnels. The dam will be of the arch type and is being designed by an Italian consulting firm. The engineer sent to the project from Italy to examine the quality of the rock spoke only his native language. It was impossible therefore to talk with him as none of the Commission's engineers understand Italian. (Fortunately for American and English engineers many of the top engineers in the employ of the Commission speak English and this

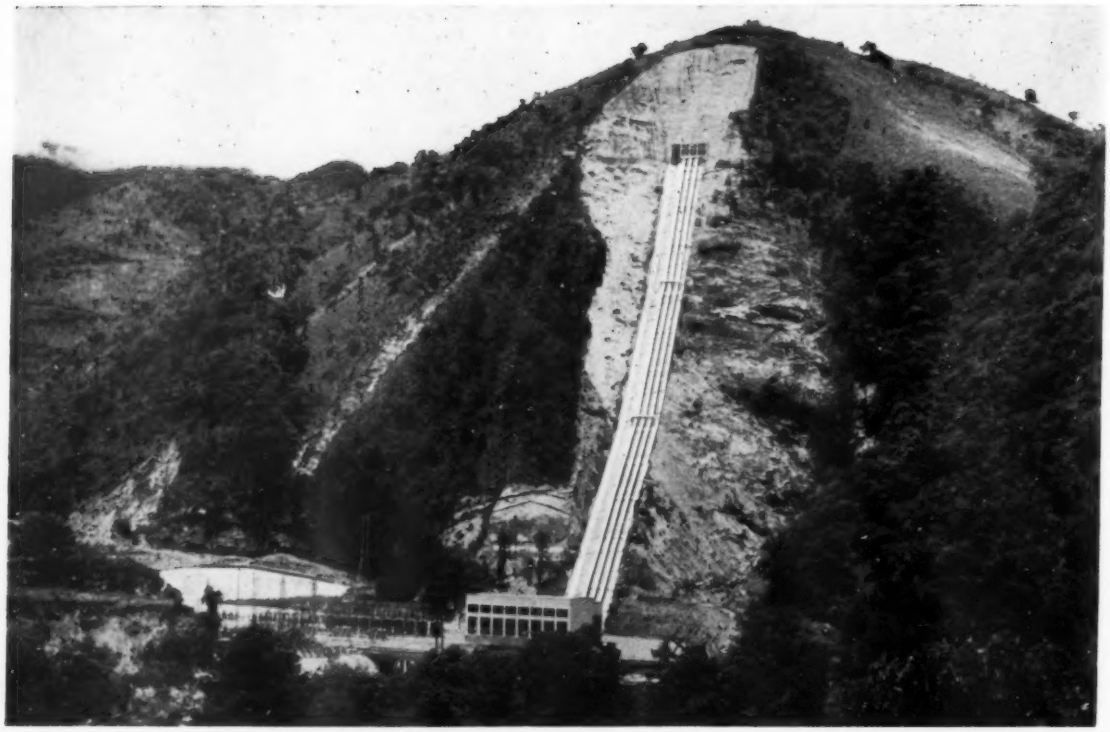


Fig. 2. Santa Barbara power plant containing three 22 5 MW sets operating under a head of 262 m.

greatly facilitated co-operation between them. At first the above dam, together with Santiago dam, also of the arch type, was to be designed by American engineers, but as the State department failed to give its approval to the design it was awarded to the Italian firm.

The reservoir created by the dam will store the water for the production of power to be transmitted to fast-growing Mexico city. There is no irrigation or flood control connected with this project. The capacity of the reservoir will be supplemented from other nearby reservoirs by means of diversion tunnels. The relatively small quantity of 1,840 cusecs will combine with a head of about 1,740 ft. to justify a plant having an ultimate capacity of 208,000 kW. There will be four units all of the Pelton type manufactured by Neyrpic, while the generators are to be furnished by a Japanese firm. The penstock will presumably be fabricated by Mexican or German companies and possibly installed by an American company. The control valves may be furnished by a Swiss company. This will result in an international accomplishment in construction, in spite of the language problem and the differences in measurement used by the various countries participating. The adoption of a common language for scientific and business purposes and a uniform system of measurement would no doubt be of great assistance in fostering international co-operation and understanding. A common business language would also be of great help in international conferences of scientists, engineers, and other professional men, not to mention diplomatic gatherings which are so common in these days.

It is not my intention to give a detailed description of this Mexican project but rather to point out the pertinent problems involved in an undertaking of this kind. The engineers of the Commission are doing a creditable job in the power development work of their country.

Although they necessarily follow the time-proven practices of the United States and Europe, they have many good ideas of their own in regard to design and construction and these are being put to good use. There are also native contractors with considerable experience in this type of work. On the other hand the steel industry is now capable of producing steels of the quality required for important structures, including pressure pipelines. It will be but a matter of time when Mexico will develop her manufacturing and construction know-how to a point to become nearly self-sufficient. The great progress made during the regime of former president Adolfo Ruiz Cortines is expected to be continued and perhaps exceeded under the newly elected president Adolfo Lopez Mateos if inflation, which is the curse of Mexico as well as of other countries south of the Rio Grande, will not make further inroads on her economy. President Mateos, former Secretary of Labour in the Cortines cabinet, is considered to be a man of high ideals and devoted to the welfare of his country. No doubt he will do his utmost to improve the economic status of Mexico and raise the standard of living of its people.

1, 2 Owing to recent administrative changes Sr. Manuel Moreno Torres replaces Sr. Carlos Ramirez Ulloa as Director General, and Sr. Fernando Hiriart, the new Sub-Director, replaces the former Sub-Director and also Sr. Cesar Jimenez Lopez as Chief Engineer.

Water Hammer Caused by Pumps

With the increasing use of pumped storage many new water-hammer problems are likely to arise. The author makes a systematic review of such cases with the aid of graphical methods

By Dr. CHARLES JAEGER

WATER hammer caused by pumps is principally of importance to designers of water distribution mains and irrigation systems. Recently, large pumps have been used for cooling-water circulation in big thermal power stations, and even larger pumps are being installed for pumped-storage schemes—new problems arise every day. Few typical cases[7, 8, 10] are solved in the standard textbooks, specialised literature dealing with a few additional cases is not readily available in English[2, 3, 4, 9] and many problems have never been discussed in print.

The aim of this article is to present a systematic review of cases of pumps feeding pressure pipes, which may have to be solved by designers.

Summary of the Graphical Method

Conjugate Water-hammer Equations

Allievi has shown that water-hammer waves travelling along a pipeline obey the following two differential equations:

$$\frac{\delta v}{\delta t}=g\frac{\delta y}{\delta x}$$

$$\frac{\delta v}{\delta x}=\frac{g}{a^2}\frac{\delta y}{\delta t}$$

where v is the water velocity and y the water pressure (measured in height of water) at the point x, and time t, a is the wave velocity (Fig. 1).

The integration of these differential equations is known to be:

$$y=y_o+F\left(t-\frac{x}{a}\right)+f\left(t+\frac{x}{a}\right)$$

$$v=v_o\mp\frac{g}{a}\left[F\left(t-\frac{x}{a}\right)-f\left(t+\frac{x}{a}\right)\right]$$

where y_o and v_o are the pressure and velocity for steady flow conditions. $F\left(t-\frac{x}{a}\right)$ and $f\left(t+\frac{x}{a}\right)$ are unknown integration functions to be determined by boundary conditions. Physically, F and f represent pressure waves travelling along the pressure pipe. (The minus sign is for pipes feeding turbines, the plus sign for a pump feeding a pressure pipe.)

The usual procedure consists of eliminating F and f. Allievi derived chains of equations of the second degree linking values of y_{i-1} and y_i, or y_i and y_{i+1} to v_{i-1} and v_i or v_i and v_{i+1}. The indices $i-1$, i, $i+1$ . . . refer to instants t_{i-1}, $t_i=t_{i+1}+\mu$, $t_i=t_{i-}+2\ \mu$, with $\mu=\frac{2L}{a}$, μ being the period of the pipe and L its length.

The graphical treatment shows that the pressure y_{x1t} and the discharge q_{x1t} at a point x and time t are bound by a linear relation to the pressure y_{XT} and discharge q_{XT} at the points X and T. When considering a wave moving against the flow (in the direction $-v$), then

$$x=X+(t-T)a \text{ and}$$

$$y_{xt}-y_{XT}=\frac{a}{gA}\ (q_{xt}-q_{XT}) \qquad \ldots (1)$$

When moving with the flow (in the direction $+v$):

$$x=X-(t-T)a$$

$$y_{xt}-y_{XT}=-\frac{a}{gA}\ (q_{xt}-q_{XT}) \qquad \ldots (2)$$

(A = pipe cross-section, which is supposed to be constant between x and X).

On a diagram (qy), equation (1) represents a straight line I with a gradient.

$$\tan\ \alpha_1=a/gA$$

and equation (2), a straight line II with a gradient

$$\tan\ \alpha_2=-a/gA \text{ (see Fig. 2)}$$

These straight lines are called the "water-hammer lines."

Boundary Conditions on the Diagram (q_1y)

For steady flow conditions, boundary conditions at the pipe ends are represented by simple curves on the diagram (q, y). Fig. 3 shows that at the upper end C of a pipe, where the pressure is assumed to be constant, the boundary condition y_o=constant is represented by a horizontal line y_o=constant.

A gate or needle valve with constant opening $A_{\psi o}$ (located upstream of a turbine) is represented by a parabola ψo. When different gate openings $A_{\psi 1}$, $A_{\psi 2}$, $A_{\psi 3}$ . . . are considered at times t_1, t_2, t_3 . . . , the conditions at the gate will be represented by a family of parabolas ψ_1, ψ_2, ψ_3 . . .

A pump characteristic can be represented by a curve Ω_0 on a diagram (q, y) where Ω_0 is the speed of rotation of the pump. Under steady conditions (Fig. 4), the pump discharge is q_o, for a pumping head y_o, and point P_o on curve Ω_o represents the flow conditions for steady flow. The curve Ω_o is derived from model test results. If the speed of rotation varies from Ω_0 to Ω_1, Ω_2, Ω_3 and so on, curves Ω_1, Ω_2, Ω_3 can be traced, derived from Ω_0 by a simple transformation. When calculating water hammer caused by pumps, the characteristics of the runner operating as a pump, as a brake and as a turbine are usually required.

The Graphical Treatment

The graphical treatment of any problem on water hammer consists of following, on a (q, y) diagram, the water-hammer lines I and II running from one boundary curve to the other, just as pressure waves travel from one end of the pipe to the other.

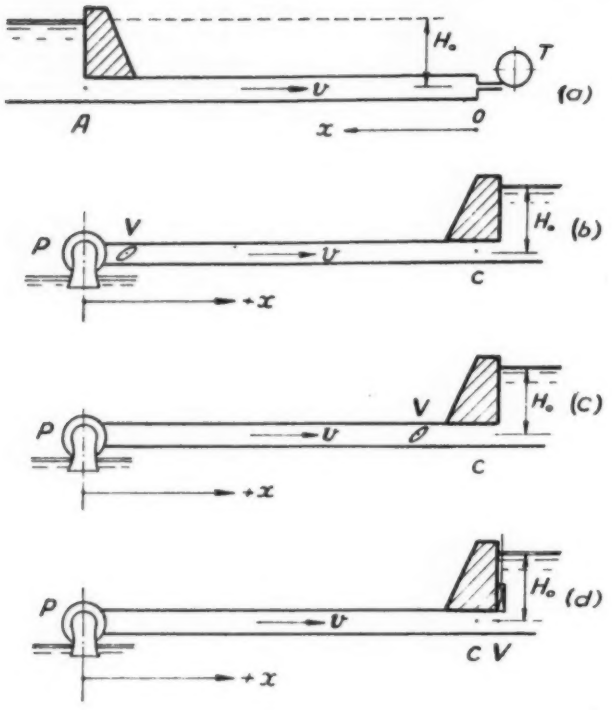


FIG 1.

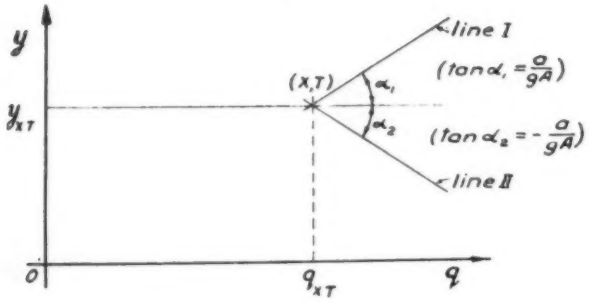


FIG. 2

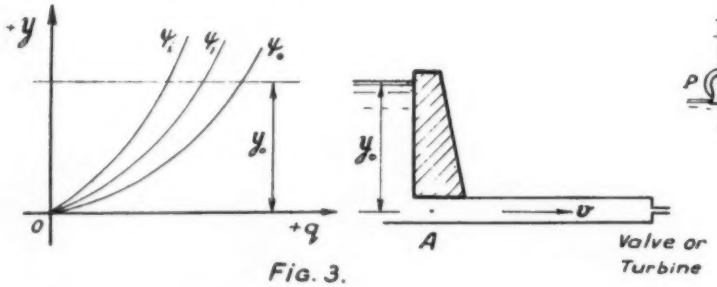


FIG. 3.

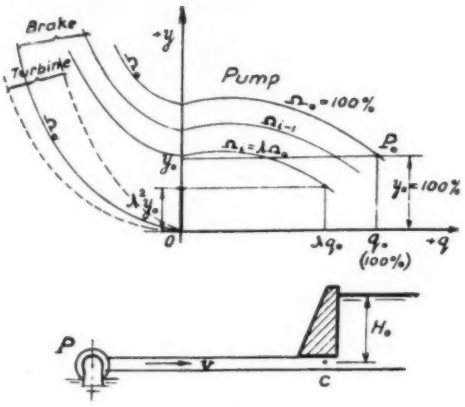


FIG. 4.

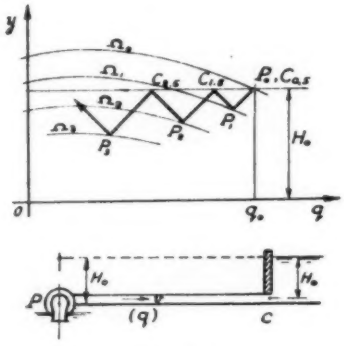


FIG 5

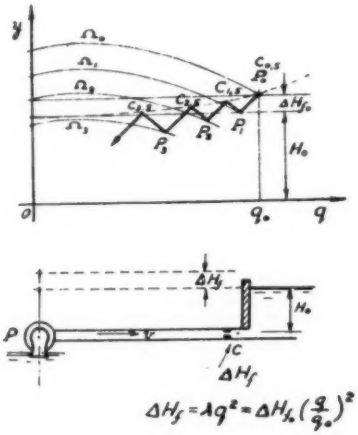


FIG. 6.

WATER-HAMMER PROBLEMS INVOLVING PUMPS

Water hammer in pressure pipes feeding turbines is usually caused by valves or turbine gates opening or closing. The turbine runner has little or no influence on water hammer developing in the pipe* and the runner is therefore not included in the calculations. It can be shown that water hammer then depends only on the pipe characteristic $\rho = av_o/2gH_o$ and the relative gate closure or opening time $\theta = \tau/\mu$. When dealing with pumps, the mass of the runner can rarely be excluded from the diagram as the water discharge is governed by the rotation of the pump, which may slow down or accelerate. Even when there is a short circuit or power failure, the pump continues to

* The momentum of the rotating masses is a most important variable in problems of turbine governing.

rotate for a while, owing to the momentum acquired by the rotating masses. Then the pump stops and reverses, unless the reverse flow of water is arrested by a flap valve.

The theorem of momentum makes it possible to write an equation relating the slowing down of the runner to the change in torque and to the moment of inertia of the rotating masses (runner plus generator or motor). The variation $\Delta\Omega$ of the speed Ω of the rotating masses produced in the time Δt is

$$\Delta\Omega=\frac{C_i}{\theta^*}\,\Delta t$$

where: $\Omega=\frac{2\pi n}{60}$ radians per second, n is given in rotations per minute.

Torque C_i absorbed by the pump is $C_i=\frac{716}{n_i}\,N_i^*$ kg. m., N_i^* being expressed in metric horsepower, or $C_i=\frac{5250}{n_i}\,N_i^*$ ft. lb., if N_i^* is in British h.p., θ^* is the moment of inertia of the rotating masses, and $\theta=\frac{WD^2}{4g}$ m. kg./sec.^{2} or lb. ft./sec.^{2}, where W is the weight of the rotating masses and D the mean diameter.

The water-hammer calculation is carried out in two stages. The pressure and discharge variations are given by the graph (q, y); speed variations are calculated step by step as the power absorbed by the pump $N_i^*=\frac{y_i q_i}{\eta_i}$ (η_i=overall pump efficiency expressed in m. kg./sec. or lb. ft./sec.) varies with y_i and q_i.

Typical Water-hammer Problems Involving Pumps

Power Failure of Pump with Large Moment of Inertia. No Gate Closing

Case 1. Power failure (short circuit). Gate or valve does not close. Friction losses neglected (Fig. 5)

This is now a classical problem[1, 3 to 7]. Before the power failure, the conditions in the pump (Fig. 5) are represented by point P_o (q_o, H_o), where q_o is the steady pump discharge, and $y=H_o$ is the pumping head. This point P_o is on the curve Ω_0, representing the pump characteristics (q, H) for the constant speed Ω_0. Q_o, H_o and Ω_0 can be absolute values or relative values ($Q_o/Q_o=100\%$, $H_o/H_o=100\%$, $\Omega_0/\Omega_0=100\%$). P_o also represents the conditions at point C, at the end of the pipeline, up to the time $\mu/2$, just before the first pressure wave starting from P_o at the time $t=o$ arrives in C at the time $\mu/2=\frac{L}{a}$. These conditions are represented by point $C_{0\cdot5}$ which is identical to P_o.

At the time $t=\mu$, the first wave reflected in C arrives at the pump, where the pump speed is now found to be Ω_1. The point P_1, representing the discharge and pressure inside the pump at the time $t_1=\mu$, must therefore be at the intersection of a straight line

$$y_{P.\,1}-y_{C.\,0\cdot5}=\frac{a}{gA}(Q_{P.\,1}-Q_{C.\,0\cdot5})$$

and the curve Ω_1.

In addition, the speed drop of the pump is $\Delta\Omega_1=\Omega_o-\Omega_1$, given by:

$$\Delta\Omega_1=\frac{C_1}{\theta^*}\,\mu$$

It is easy to find the next points:

$C_{1\cdot5}$, $C_{2\cdot5}$, $C_{3\cdot5}$, etc., are all on a horizontal line $y=H_o$ because the pressure at point C remains constant ($y=H_o$) in spite of the decreasing discharge ($q_i<q_o$). The other series of points P_1, P_2, P_3 . . . are on the pump characteristics Ω_1, Ω_2, Ω_3, corresponding to the falling speed of the pump, with $\Delta\Omega_i=\Omega_{i+1}-\Omega_i$ given by the equation of momentum for the rotating masses.

Case 2. Power failure, same as for Case 1. Friction losses included (Fig. 6)

The friction losses are supposed to be concentrated at point C, at the far end of the pipe ($x=L$). They can be represented by a parabola

$$\Delta H_f=\lambda q^2$$

which replaces the horizontal $y=H_o$=constant of the previous case.

For $q=q_o$ the pressure at the pump is $y_o=H_o+\lambda q_o^2$; the pressure at point C is also $y_{co}=H_o+\lambda q_o^2$. For discharge $q<q_o$, the pressure just before C decreases to $y_c=H_o+\lambda q^2<y_{co}$. The points $C_{0\cdot5}$, $C_{1\cdot5}$, $C_{2\cdot5}$ . . . are now on this parabola and the water hammer lines I and II intersect on this parabola and on the curves Ω_1, Ω_2, Ω_3 . . .

Case 3. Power failure as for Cases 1 and 2. Head H_o small or negligible compared to λq_o^2 (Fig. 7)

Fig. 7 shows a solution to this case. (The lowest possible value of H_o is $H_o=V_o'^2/2g$, V_o'=outlet velocity.)

Closure of Gates; Pump with Large Moment of Inertia Running at Normal Speed

Case 4. Valve located near the pump. Slow closure. No friction losses (Fig. 8)

Conditions inside the pump are represented by the curve Ω_o. Between the upstream and downstream sides of the valve or gate there is a pressure loss given by the equation of momentum (Borda formula)

$$\Delta H_v=\left(\frac{q}{q_o}\right)^2\frac{v_o^2}{2g}\left(\frac{1}{\psi}-1\right)^2$$

where ψ is the relative effective gate opening.

These valve losses have to be subtracted from the curve Ω_0 representing conditions in the pump running at constant speed. The conditions on the other side of the valve at times 1, 2, 3, . . . i . . . are obtained by subtraction of the corresponding losses ΔH_{vi}, and the points V_1, V_2, V_3 . . . representing conditions at the valve are on the curves ψ_1, ψ_2, ψ_3 . . . (Fig. 8). Points $C_{0\cdot5}$, $C_{1\cdot5}$, $C_{2\cdot5}$ . . . are on the horizontal $y=H_o$=constant, and points P_1, P_2, P_3 are on Ω_0.

Case 5. Gate or valve closure as for Case 4. Friction losses included (Fig. 9)

For steady flow conditions the pressure in the pump is $H_o+\Delta H_{fo}$ where $\Delta H_{fo}=\lambda q_o^2$. This is also the pressure at C, just before the point where friction losses are supposed to be concentrated.

The points $C_{0\cdot5}$, $C_{1\cdot5}$, $C_{2\cdot5}$ . . . are now located on the parabola $\Delta H_f=\lambda q^2$ instead of on the horizontal $y=H_o$.

Case 6. Gate or valve closure as for Case 4, high friction losses, low static head H_o

Fig. 10 shows the pressure diagram for such conditions.

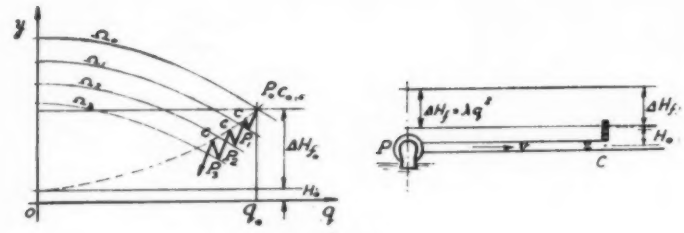
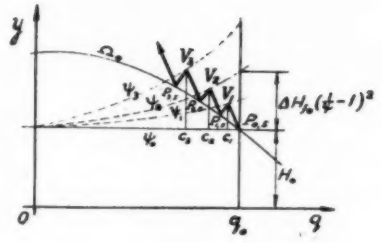


Fig. 7.



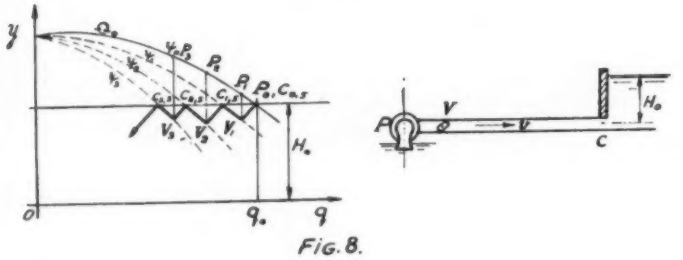


Fig. 8.

Fig. 11.

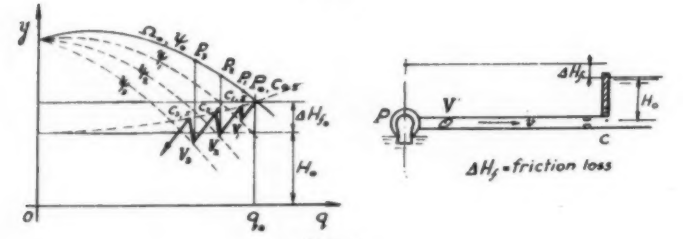


Fig. 9

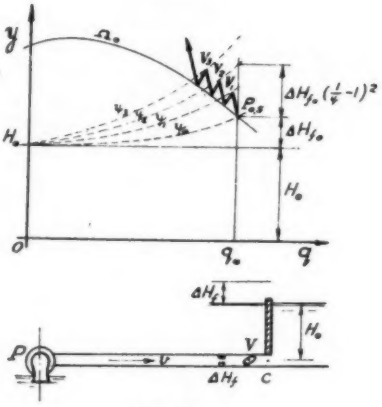


Fig. 12.

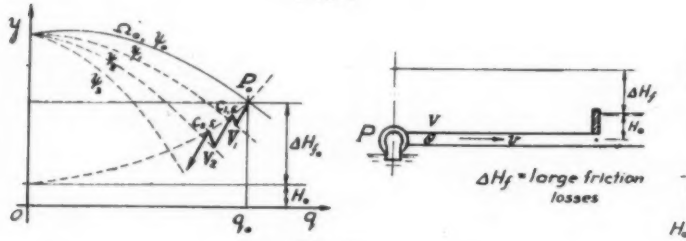
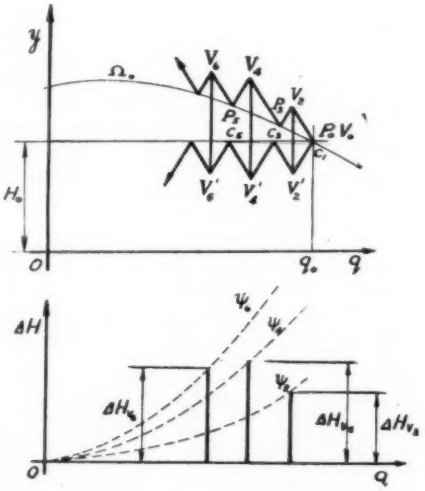


Fig. 10.



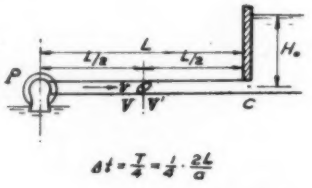


Fig. 13.

Case 7. Closure of a valve or gate at the outlet end of the pressure pipe. No friction losses (Fig. 11)

Depending on the design of the valve or gate, the losses through the valve can be represented either by a formula of the type ("Borda" loss):

$$\Delta Hv = \left(\frac{q}{q_o}\right)^2 \frac{v_o^2}{2g} \left(\frac{1}{\psi} - 1\right)^2$$

$\Delta H_{vo} = o$ for $\psi = 1$ assuming there are no losses when the valve is open and $\psi = 1$.

or $\Delta H_v = \left(\frac{q}{q_o}\right)^2 \frac{1}{\psi^2} \Delta H_{vo}$

$\Delta H_{vo} = \frac{q_o^2}{2gA_o^2}$, representing the energy head required for the discharge q_o to pass through the valve opening A_o when fully open $\psi_o = 1$ (Torricelli formula). Both formulae are of the second degree, represented by parabolas $\psi_o = 1$, ψ_1, ψ_2, ψ_3 . . . The Borda type formula is more likely to match actual conditions. As

the disturbance starts at the gate, the pressure-discharge conditions remain unchanged at the pump until time $\mu/2$ (point $P_{0\cdot5}$). A wave starting from P just before $\mu/2$ travels in the direction of $+v$ and is represented by a water-hammer line II, which cuts the curve ψ_1 at point V_1. The points $P_{0\cdot5}$, $P_{1\cdot5}$, $P_{2\cdot5}$ . . . are on the curve Ω_0. The points V_1, V_2, V_3 . . . are on the curves ψ_1, ψ_2, ψ_3 . . . , and points C_1, C_2, C_3 . . . are on the line $y=H_o$.

The closing of a gate or valve near the pump causes a pressure drop; the closing of a gate at the other end of the pressure pipe causes a pressure rise.

Case 8. Valve closure as for Case 7. Friction losses included (Fig. 12)

The losses through the valve at the end of the pipe are supposed to be

$$\Delta H_v=\left(\frac{q}{q_o}\right)^2 \frac{v_o^2}{2g}\left(\frac{1}{\psi}-1\right)^2$$

The friction losses are given by

$$\Delta H_f=\lambda q^2=\Delta H_{fo}\left(\frac{q}{q_o}\right)^2$$

Both functions are represented by parabolas as on a diagram (q,y). At any time, the sum of the losses is also a parabola

$$\Delta H_v+\Delta H_f=\left(\frac{q}{q_o}\right)^2\left[\frac{v_o^2}{2g}\left(\frac{1}{\psi}-1\right)^2+\Delta H_{fo}\right]$$

as shown in Fig. 12. The water-hammer line diagram is similar to Fig. 11.

Case 9. Slow closure of valve located somewhere along the pipeline. With or without friction losses (Fig. 13)

The pump characteristic is curve Ω_0 on which all the points P (like P_1, P_3, P_5, . . .) are located. The characteristic of the pipe outlet is the horizontal line $y=y_o=$constant. All the points C (like C_1, C_3, C_5, . . .) are on this line. The losses through the gate can be calculated beforehand (Borda loss formula), as shown on curves ψ_2, ψ_4, ψ_6 . . . These losses are equal to $\Delta H_{v2}=V_2\,V_2^1$, $\Delta H_{v4}=V_4\,V_4^1$, $\Delta H_{v6}=V_6\,V_6^1$ . . .

Assuming the valve to be located in the middle of the pipe, it is convenient to choose the unit of time for the water-hammer calculations Δt:

$$\Delta t=\frac{\mu}{4}=\frac{1}{4}\cdot\frac{2L}{a}$$

and make $t_1=t_0+\Delta t$, $t_2=t_0+2\Delta t$, $t_3=t_0+3\Delta$t . . . When the gate begins to move ($t=t_0=0$), the conditions along the whole pipe are the same and are represented by $q=q_o$ and $y=y_o$ on Ω_0. Point V_0 is on Ω_0 with co-ordinates (q_o, y_o). The same conditions are valid for points P and C up to time $t_1=\Delta t$. Points C_1 and P_1 are identical with point V_0. This point is the beginning of the water-hammer line diagrams: lines $P_1\,V_2\,P_3\,V_4\,P_5\,V_6$ . . . and $C_1\,V_2^1\,C_3\,V_4^1\,C_5\,V_6^1$ . . .

When friction losses are considered, it will be assumed that they are concentrated at point C. The line $y=y_o$ will be replaced by a pressure loss parabola showing the boundary condition in C.

SIMULTANEOUS POWER FAILURE AND GATE CLOSURE

Case 10. Gate closure occurs in a time τ larger than μ, ($\tau=n\mu$) immediately after the power failure. Valve located near pump. No friction losses (Fig. 14)

This is a combination of Cases (1) and (4). The power failure causes the speed of the pump to drop: curves Ω_1, Ω_2, Ω_3 will be traced as for Case (1). The closing of the valve, which is supposed to be started automatically and immediately, causes pressure losses in the pipe. The points like P_i, representing conditions in the pump, are located on the pump characteristics Ω_i. Conditions after passage through the valve are represented by the points V_i so that $V_i\,P_i=\Delta H_{vi}=$pressure loss in the closing valve. The points $C_{i-0\cdot5}$, $C_{i+0\cdot5}$, . . . are all located on the horizontal $y=H_o$. For practical reasons, it is advisable to trace the parabolas ψ_i representing the pressure losses (Borda losses) in the valve, on a separate sheet of transparent paper Point 0* of this mobile $(q, \Delta H)$ diagram is thus moved on the y axis of the (q, y) diagram, so that curve ψ_i correctly cuts Ω_i in P_i. When the water moves up the pressure pipeline, the pressure after the valve is less than in the pump and point V_i is located below P_i. When the direction of flow in the pipe is reversed ($q>o$), the pressure in the valve is higher than in the pump and V_i^1 rises above P_i^1 (Fig. 14).

The pressure disturbance starts at the lower end of the pipeline and the first water-hammer line to be traced is of the type I.

Case 11. Same as for Case 9, but with friction losses included (Fig. 15)

The points like $C_{i-0\cdot5}$ and $C_{i+0\cdot5}$ are located on the friction loss parabola. The steady state conditions are represented by point $(q_o, H_o+\Delta H_{fo})$ (Fig. 15).

Case 12. Rapid closing of a check valve after power failure (Fig. 16)

Fig. 16a shows that after the power failure the pump speed decreases from Ω_0 to Ω_i. For $q=o$ when the flow reverses, the check valve suddenly closes ($\tau<\mu$), causing a sharp pressure rise. This pressure rise is even sharper if the valve closure is delayed (Fig. 16b).*

Case 13. A slow-closing valve is located at the upper end of the pipe (Fig. 17)

The conditions in the pump are given by a family of Ω_i curves. At the other end of the pipeline, conditions at the valve are described by pressure loss curves ψ_i. Fig. 17a has been traced assuming that closure of the valve starts immediately, before the pump actually slows down. Assuming conditions to be undisturbed at the pump up to time $t=\mu/2$ or $i=0\cdot5$, then $\Omega_{0\cdot5}=\Omega_0$. The intersection of a water-hammer line type II with ψ_1 gives the first point of the diagram.

Assuming that the gate starts closing immediately after the slowing down of the pump, conditions are as represented in Fig. 17b. When both pump and valve start their movements simultaneously, conditions are as shown in Fig. 17c.

Case 14. Same case as 13, friction losses being included (Fig. 18)

At the upper end of the pipe, where friction losses are supposed to be concentrated, a second friction loss parabola has to be introduced, as shown on Fig. 18.

Case 15. A valve closing rapidly at the upper end of the pipeline

This would cause unduly high pressure rises in the pipe.

* See Schnyder, *Von Roll Mitteilungen*, No. 3/4, 1943, Fig. 34b and 34c.

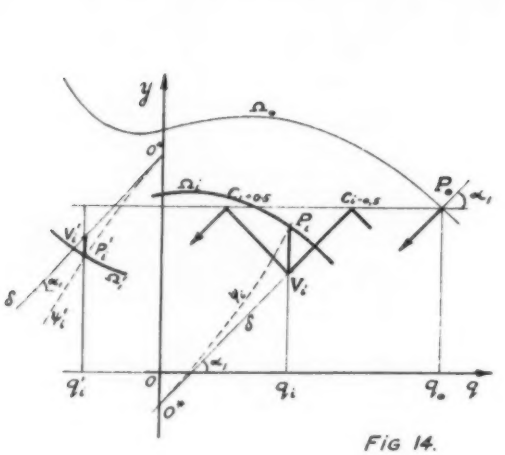
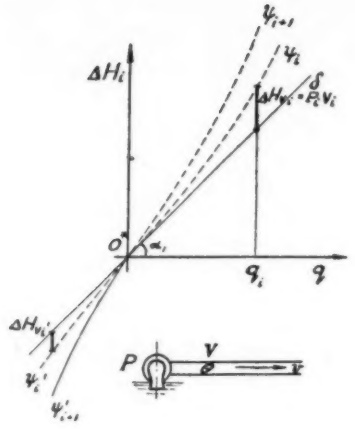


FIG 14.



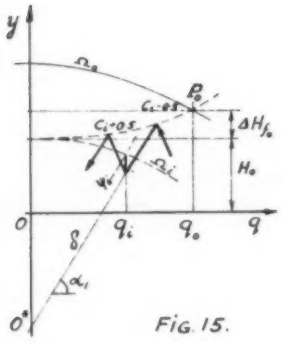


FIG. 15.

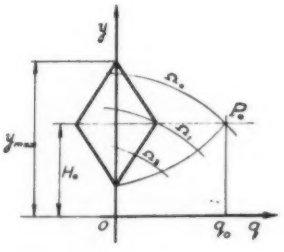


FIG. 16a

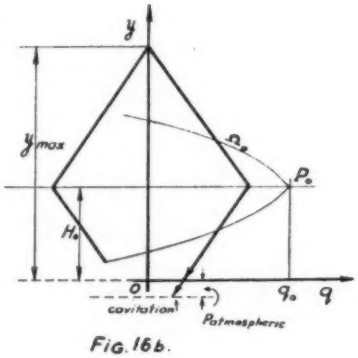


FIG. 16b.

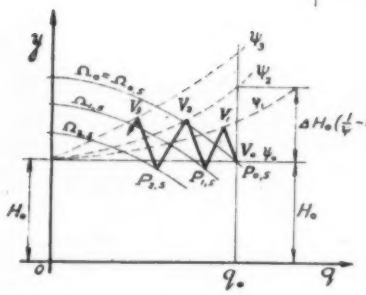


FIG. 17a.

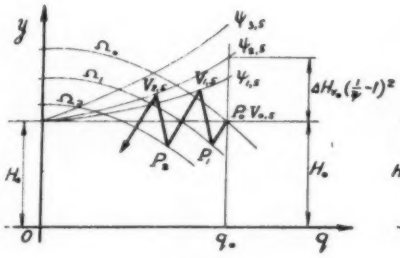


FIG. 17b

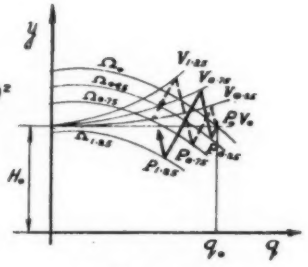


FIG. 17c.

Case 16. The slow-closing valve is located somewhere along the pipeline. Friction losses ignored or included (Fig. 19)

The valve is supposed to be located at point V in the upper third of the pipeline. The unit of time for the calculation is $\Delta t=\mu/6=\frac{1}{6}\cdot\frac{2L}{a}$. The losses through the valve are $\Delta H_{v2}=V_2\ V_2^1$ or $\Delta H_{v4}=V_4\ V_4^1$ . . . and can be calculated beforehand when tracing the curves ψ_2, ψ_4 . . . At the time $t=o$, the pump begins to slow down, and the valve starts to close. Points P_o and V_o are both on curve Ω_0 with $q=q_o$, $y=y_o$. Waves reach D and C just at the time $t=\Delta t=t_1$, and points C_1 and D_1 are identical with V_o, P_o. The water-hammer line $D_1\ V_2$ and $C_1\ V_2^1$ gives $V_2\ V_2^1=\Delta H_{v2}$. The line $D_1\ P_2$ (identical with $C_1\ V_2^1$) cuts Ω_2 at point P_2. The points V_2, V_2^1 and P_2 are at the origin of the line diagrams.

$$D_1\ V_2\ D_3\ P_4\ D_5\ V_6\ \ldots$$
$$C_1\ V_2^1\ C_3\ V_4^1\ C_5\ \ldots$$
$$P_2\ D_3\ V_4\ D_5\ P_6\ \ldots$$

If friction losses concentrated at point C are to be considered, the line $y=y_o$=constant will be replaced by a friction loss parabola.

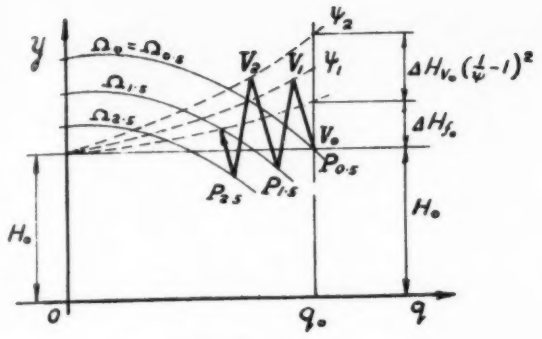


FIG. 18.

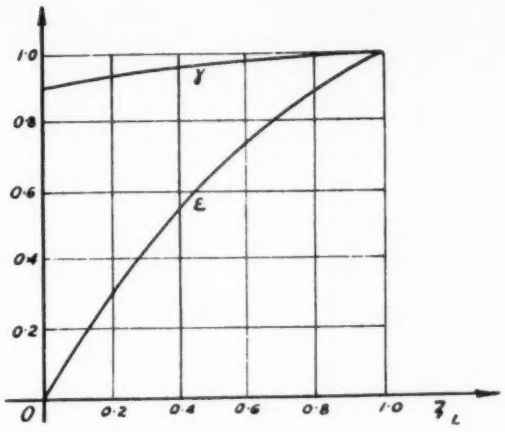
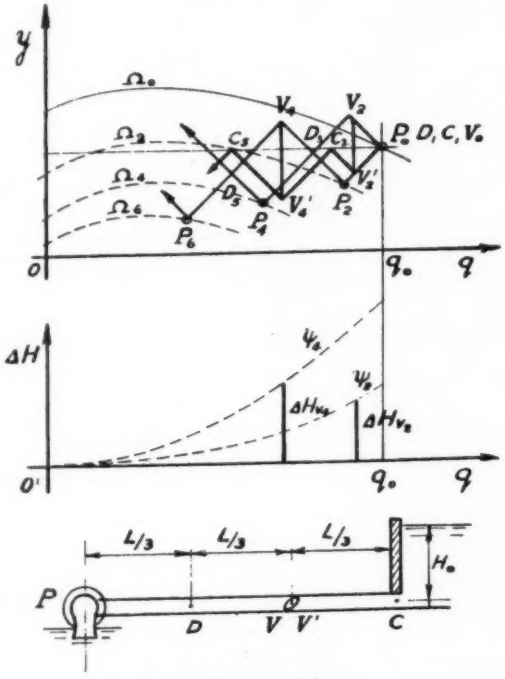


FIG. 20.



$$\Delta t = \frac{T}{6} = \frac{1}{6} \cdot \frac{2L}{a}$$

FIG 19.

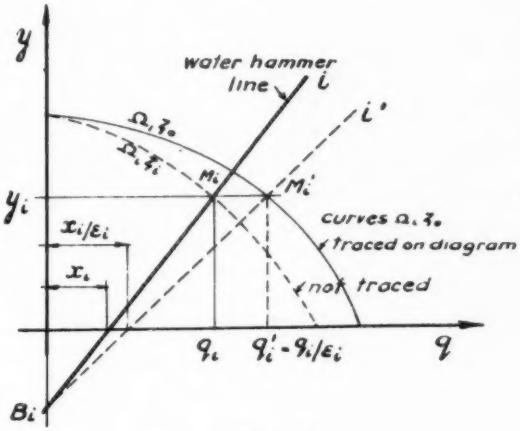


FIG. 21.

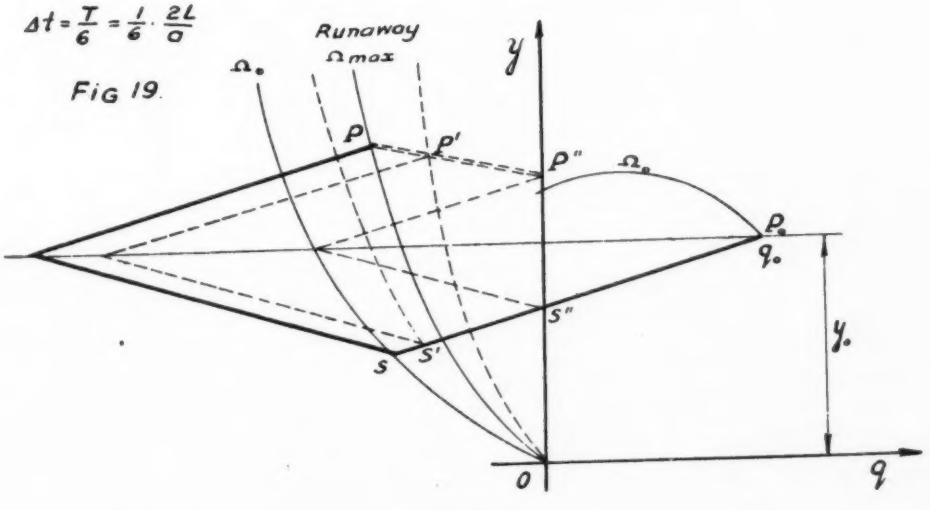


FIG. 22.

Case 17. Pumps provided with movable guide vanes

A diagram of characteristic curves (q, y) for varying pump speed Ω_i is obtained as usual for full guide vane opening, $\zeta_o = 100\%$. The corresponding discharges are $q_{\zeta o}$. For partial opening ζ_i ($\zeta_i \leqslant \zeta_o$) of the guide vanes, the discharge through the pump is $q_{\zeta i}$ and

$$\epsilon_i \ (\zeta_i) = q_{\zeta i}/q_{\zeta o} = \epsilon_i$$

is a function which can be obtained from model tests for different values of ζ_i and Ω_i. Similarly the torque C_i absorbed by the pump can be measured for $\zeta_o = 100\%$ and for varying values ζ_i of the guide-vane opening so that a function

$$\gamma_i \ (\zeta_i) = C_{\zeta i}/C_{\zeta o} = \gamma_i$$

can be established on the basis of measurements on the model. Tests have shown that $\epsilon(\zeta_i)$ and $\gamma(\zeta_i)$ depend on ζ_i alone and not on q_i or y_i (see Fig. 20).

The graphical water-hammer method would require the tracing, not only of one family of curves (Ω_i, ζ_o) on the (q, y) diagram, but for every ζ_i value of a new family of curves (Ω_i, ζ_i). This would be impracticable.

It can be seen (Fig. 21) that there is geometrical affinity between the curves $\Omega_i \ \zeta_i$ and the corresponding curves $\Omega_i \ \zeta_o$. For y_i = constant, $q_i' = q_i/\epsilon_i$, $M_i \ (q_i, y_i)$ being on curve $\Omega_i \ \zeta_i$ and $M_i' \ (q_i', y_i)$ on curve $\Omega_i \ \zeta_o$. The straight line i' cuts line i at point B_i on the axis y. To any point $M_i \ (q_i, y_i)$ on curve $\Omega_i \ \zeta_i$, there is a corresponding point $M_i' \ (q_i', y_i)$ on curve $\Omega_i \ \zeta_o$ as shown on Fig. 21. Point M_i corresponds to the true discharge q_i and pressure y_i in the pump, and is being used for tracing the water-hammer diagram. Point M_i' immediately shows what pump speed Ω_i corresponds to this point M_i (as Ω_i is the same for the curves $\Omega_i \ \zeta_i$ and $\Omega_i \ \zeta_o$). Only the curves $\Omega_i \ \zeta_o$ need to be traced and not the curves $\Omega_i \ \zeta_i$. The true value of the torque $C_{\zeta i}$ is given by $C_{\zeta i} = \gamma_i \ (\zeta_i) \ (C_{\zeta o}$.

PUMPS WITH NEGLIGIBLE MOMENT OF INERTIA θ

This case has been illustrated by O. Schnyder (1943) (see Fig. 22). Point $P_o \ (q_o \ y_o)$ represents steady pumping conditions at pump speed Ω_o. As soon as there is a power failure, the pump goes through the point $\Omega = 0$ (parabola $\Omega = 0$), and then reverses and overspeeds (parabola $\Omega_{max.}$). The corresponding water-hammer lines $P_o \ S \ P$ show the maximum pressure rise at P. If a flap valve closes as soon as the water reverses ($q = 0$), then the lines $P_o \ S'' \ P''$ show the pressure rise at P'' (on the y axis). For intermediary gate opening, the lines will be $P_o \ S' \ P'$.

PRESSURE PIPES WITH PUMPS AND AIR VESSELS

This problem is not dealt with here. See Bibliography, Nos. 3, 4, 5, 9, 11.

ANALYTICAL TREATMENT

Analytical treatment of water-hammer problems can always be used instead of graphical methods. It is recommended in special cases (Dériaz pump) and for programming calculations to be done on the digital computer.

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Committee on the Fatigue of Engineering Structures

A committee to review current research needs on the fatigue of engineering structures and to survey existing research facilities has been set up by the Council for Scientific and Industrial Research following an approach from the Institution of Civil Engineers. The committee will not include aircraft structures, reinforced-concrete structures, or metal physics in the scope of their review, though information gained in these fields will be used. Professor Sir Alfred Pugsley, of the Department of Civil Engineering, Bristol University, has been appointed chairman. The other members of the committee are: Sir Donald G. Bailey, Mr. T. Baldwin, Mr. H. L. Cox, Mr. O. A. Kerensky, Mr. H. M. Pemberton, Mr. C. E. Phillips, Professor S. C. Redshaw, Dr. P. B. Walker and Dr. R. Weck.

The committee's terms of reference are: "To review current research needs on fatigue of engineering structures (Metal), to survey existing research facilities and to make recommendations to the Department of Scientific and Industrial Research."

The committee is interested in examining records of failures or accidents which might have been due to structural fatigue, even if fatigue was not recognised as the initial cause. Such information may be helpful in revealing areas in which further research work is needed.

St. Lawrence Seaway. An interesting account is given of the St. Lawrence Seaway in an article written by John D. King and published in the spring edition of *The Vickers Magazine*. This refers mainly to the new transport facilities afforded and is not primarily concerned with the power aspects of the scheme. Much of the equipment for the canal system was, of course, made by the Vickers concern, for instance, the lock gates, sluice gates, mitre gates, etc. In the past the trip from Montreal to Prescott included 21 locks and involved a lift of 225 ft.; with the new canal system the same lift is accomplished by seven locks.

Fig. 1. Reinforcing the top heading, using Blaw Knox concrete pump

The Harrsele Tailrace Tunnel

A description of the procedure in driving the top heading of the Harrsele tunnel was given in our November, 1956, issue. This operation was completed on November 21, 1955. Immediately thereafter the second stage of the tunnel drilling began, which involved the blasting of the 8·7 m. high bench, and a detailed exposition of this operation is given in the following article

By RAGNAR AHLSTRÖM and JÖRGEN JÖRGENSEN,
Chief Engineers, Harrsele AB

THE blasting of such a comparatively high tunnel bench as obtained at Harrsele implied an advance tunnel-blasting technique, and an account of this bench-blasting operation may therefore be of interest.

The Harrsele tunnel has a cross-sectional area of 260 sq. m. (increased from 250 sq. m. during the course of the blasting operation), a width of 15 m., a height of 18·4 m. and a length of 3,400 m., the net volume of rock excavated amounting to 885,000 cu. m. The tunnel was driven with crews operating from each end. In the first place transport tunnels having an area of 44 sq. m. were driven, the upstream tunnel being 450 m. long and the downstream tunnel 120 m. long. The net volume of rock excavated for the transportation tunnels amounted to 25,000 cu. m. Subsequently a top heading with a cross-sectional area of 130 sq. m. (height 9·7 m.) was driven using the full-face method* and finally the bench, also having a cross-sectional area of 130 sq. m. (15 × 8·7 m.), was blasted.

The work of building the power plant, which is being constructed by the Company itself, began on July 1, 1953. The first round was fired on October 12, 1953, for the transportation tunnel in the upstream section and the last round was fired on April 9, 1957, for the bench in the downstream section of the tunnel. The total working time for the blasting operation (including transportation tunnels and reinforcements) was thus 3½ years.

* *See* WATER POWER, November 1956, page 407.

Bench Blasting—General

According to the working schedule the tunnel was to be submerged on August 1, 1957. This necessitated that the blasting operations should be completed early in the spring because time must be available for carrying out tunnel floor cleaning, any remaining reinforcements, and a fairly extensive concrete construction in the connecting gallery between the tunnel and the surge chamber. This connecting gallery joined the transport tunnel in the upstream section and was used right up to the end of the operations for the outward transport of muck from the tunnel floor cleaning as well as machines and material employed in the blasting operations for both the tunnel and the underground power plant. Thus, after the break-through in the top heading it was a matter of urgency to get the bench blasting well under way because the available time was short.

Unfortunately the start of the blasting operation in the upstream section was delayed considerably. It was discovered that the rock was kaolinised to a certain extent—a phenomenon that was uncommon and interesting from a geological point of view, but exceedingly unpleasant and expensive for the tunnelling work, as there was a risk of the kaolin-filled fissures disintegrating with subsequent falls. In consultation with our geologist, Professor Asklund, and Mr. Fröman, Inspector of Mines, it was decided to line certain sections of the ceiling and walls of the top heading with concrete, and after having blasted the bench the concrete lining of the walls would be continued down to the completed tunnel floor. This applied to a continuous stretch of about 350 m. in length and a number of shorter stretches. These very comprehensive reinforcements in the top heading could not be carried out in a reasonable manner at the same time as the blasting operation was in progress, so the reinforcements were carried out at an accelerated tempo and were completed in the beginning of May 1956.

Not until then could the bench blasting in the upstream section begin in earnest. The first major round was fired on May 9, and this stage of the bench-blasting operation, during the course of which a 1,658 m. long bench was blasted, continued until February 20, 1957, when the break-through took place against the earlier blasted bench in the downstream section.

The blasting of the bench in the lower half of the tunnel began on December 27, 1955, at a distance of 565 m. from the mouth, blasting downwards from the bottom of the top heading to the completed tunnel bottom. The operation was carried upstream about 1,000 m. and was discontinued on September 21, 1956, at the point where it was to be met by the upstream benching on February 20, 1957. The blasting of the remaining bench in the downstream section was continued, as mentioned above, until the beginning of April, 1957.

The total working time for the bench-blasting operation, with the exception of about 100 m. in the upstream end, which it was possible to blast independently of the reinforcements in the top heading,

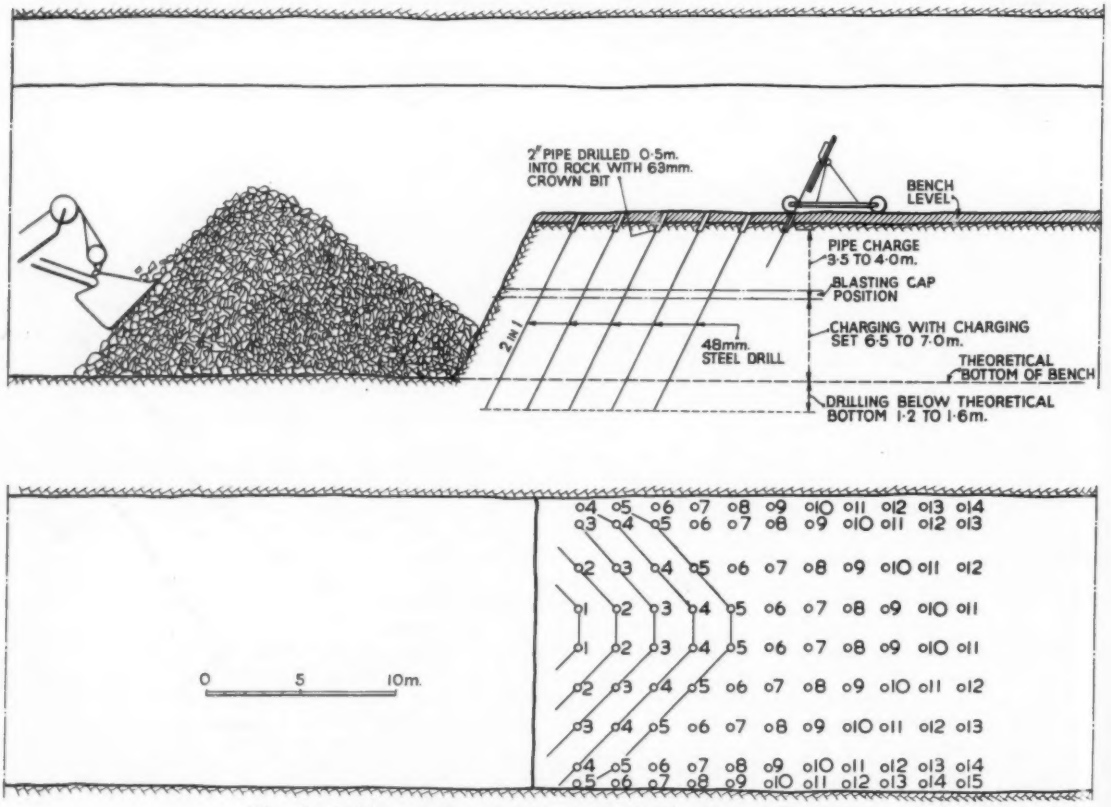


Fig. 2. Drilling pattern used for bench blasting at Harrsele

Fig. 3. Charging with Nitroglycerin AB loading apparatus

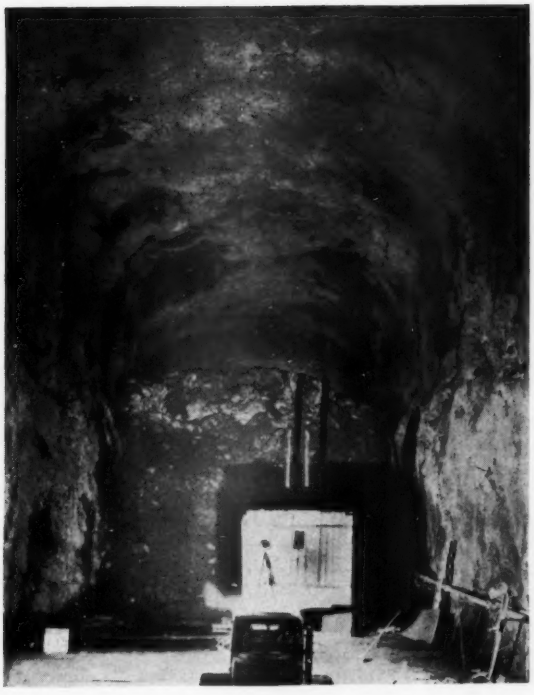


Fig. 4. Full sectional view of Harrsele tunnel

thus amounted to about 15½ months. During this period the blasting in the upstream section could not be carried on for a little more than four months because of reinforcement work in progress.

The operations that remained after the completion of the bench blasting were completed on June 15, 1957. After that time the water was allowed to rise gradually and the tunnel was completely submerged during the period July 31–August 1, 1957, by removing the multiple arches below the mouth of the tunnel.

Data for the bench blasting are as follows:—

Drilling pattern (see Fig. 1)
Bench width: 15 m.
Bench height: 8·7 m.
Inclination of holes: 2 : 1.
Burden, horizontally measured: 2·2 m.
Burden, actual: 2·0 m.
Hole spacing: about 1·9 m.
Interval between the run of holes: c/c. 2·0 m.
Depth of holes:
(a) through rubble: 0·5–1·0 m.
(b) through rock: 11·0–11·5 m.
(c) Under theoretical bottom: 1·2–1·6 m.
(included in (b))
Total hole depth: about 12·0 m.
Drilling meterage: 0·36 m_v/cu. m.

Drilling equipment

Specially designed jumbo with 9 rock drills.

Type of rock drill—Atlas Copco chain-fed BBC42 RBL mounted on chain feed BMM41 K152 having a feed length of 4·8 m.

Drill steels: Sandvik 1¼ in. extension drill steels with rope thread, Leyner shank, and 48 mm. Coromant tungsten-carbide 4-cross bits.

For "extra drilling" after the jumbo there were at each working site 1 Atlas Copco wagon drill type BVB 12 and 1 type BVB 21. These machines were employed for the purpose of avoiding interruptions in drilling from the jumbo. If the drilling of a hole was delayed, e.g., on account of the breakdown of a machine, the jumbo was rolled to the next row of holes and the so-called "idle rock drill" stepped in. Moreover, the "idle" rock drill is used for drilling holes which have collapsed and occasionally for the drilling of extra holes. These machines, however, were needed to be used only to a very limited extent.

Charging (bottom diameter 48 mm.):
Bottom charge: 2·0–2·5 kg./m.
The charging height for the bottom charge: 6·5 m.

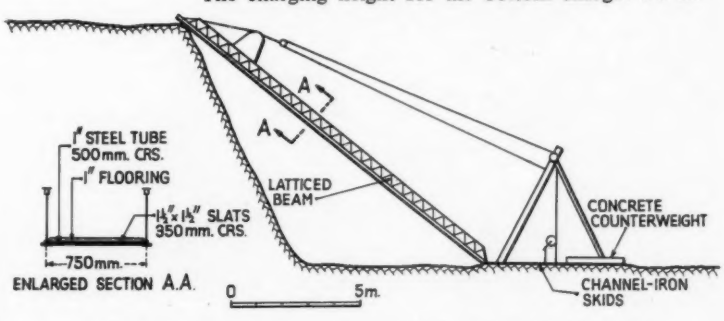


Fig. 5. Movable transport trestle, or "Jacob's ladder"

Fig. 6. Looking down the tailrace tunnel from the foot of the bench. Note the heap of spoil in the foreground

Column charge: 1·0 kg./m.
The charging height for the column charge: 4·0 m.
Uncharged hole: 1·0–1·5 m.
Dynamite consumption: about 0·6 kg./cu. m.

Charging was done with Nitroglycerinaktiebolaget's pneumatic loading apparatus type P3 (see Fig. 3). Firing was with electric short-delay detonators. For firing sequence see drilling pattern: Size of round normally 9 to 12 rows = 81 to 108 holes = 2,600 to 3,600 cu. m. During the breaking-in period rounds of 4 rows were fired.

Loading. Marion 93 M with buckets of 1·9 cu. m. capacity.

Boulder blasting occurred approx. 5 times per 1,000 cu. m.

Loading capacity 65–70 cu. m./hour = average monthly value, including interruptions.

Muck out by means of 14 ton Euclid trucks with specially designed platform body having a capacity of 5·8 cu. m. solid theoretical rock per truck load.

Output of work (3 drillers + 5 chargers. 9 rock drills). Average monthly value during August–October 1956:
Total per effective working day 9·4 m. bench = 4·25 rows = 38·3 holes = 459 drilled metres.
Drilled metres per man and shift: 153 m.
Drilled metres per man and hours, excluding charging: 20·4 m.
Drilled metres per rock drill and hours: 6·8 m.
Drilled metres per man and hours, including charging: 7·7 m.
Includes time for interruptions, collaring and setting up.

Organisation, Labour Force, Monthly advances, working Time

Most of the time the tunnel was driven with tunnel crews operating from each end. Drilling, charging and firing were carried out in one shift, loading in three shifts, scaling in connection with blasting in three shifts and after-scaling in two shifts.

The three-shift operation involved considerable wear and tear on the excavators and trucks, but it was possible to arrange sufficient time for repair and maintenance work because (1) the current regulations governing working hours for underground three-shift operations stipulate work during 16 of the 18 shifts per week and (2) by two "idle shifts" per week being included in the loading and haulage shifts. At these idle shifts the loading operation was interrupted and the personnel occupied with sundry work in the tunnel which were planned in advance. When the repair men were ready with the overhauling and repair, loading and haulage began immediately. Often the interruption did not amount to the whole shift. The fleet of vehicles were thus in operation for a little more than 14 shifts per week and this system worked satisfactorily.

The composition of the personnel will be seen from the table below.

PERSONNEL				
Jointly for both sites				
Engineer in charge of section	1			
Foreman for repair workshop and foreman for electrical workshop	2			
Layer-out of drilling patterns	1			
Time recorder	1			
For each working site				
Senior foreman	1			
Shift foreman	3	4 × 2	8	13
Rock blasting crew				
Drillers and chargers (including foremen)			8	
Excavator operator	3	11 × 2		22
Other workers				
Pre-scalers (work in top headings)			9	
Scalers (after each round)			6	
After-scalers			4	
Excavator greaser			3	
Miscellaneous labour (service personnel)			9	
Grinders of drill steel			1	
Rock drill repairman			1	
Compressor operator			1	
Shift electricians			3	
Excavator repairman			1	
Tractor drivers			3	
Truck drivers			21	
Mine car tippers			3	
Sump pump operators	3	68 × 2		136
Total for both working sites				176 men

Total working time per cu. m. of rock (excluding reinforcement work) for the complete labour force. Refers to above-mentioned blasting of 1,658 m. bench.

	hours per cu. m.
Drilling, charging and firing	0·057*
Mucking-out of rounds (tractor work)	0·014*
Loading of broken rock	0·054*
First scaling (pre-scaling and after each round scaling)	0·034*
After scaling	0·081
Haulage of broken rock	0·129
Transport of explosives	0·020
Drill steel grinding	0·016
Repair of rock drills	0·025
Repair of drill wagons and scaler platforms	0·053
Work on hoses, couplings and pipelines	0·045
Electric installations (plant, running and maintenance)	0·045
Road building and maintenance	0·019
Tipping maintenance	0·021
Manufacture of charging tubes, etc.	0·009
Total	0·622†

* These operations, totalling 0·159 hours per cu. m., have been carried out at earlier-described full-force blastings by the rock-blasting crew. For the Harrsele top heading the working time was 0·287 hours, for Dönje 0·343 hours (125 sq. m.) and for Hjälta 0·425 hours (135 sq. m.).

† For the complete bench blasting, 3,400 m. long, the corresponding figure is 0·714 hours per cu. m.

Compressed-air, Water and Electricity Supplies

Compressed air, flushing water for the rock drills and electric current were supplied to the working sites from both ends of the tunnel. There was no connecting drift to the top heading along the tunnel stretch. Drilling, charging and prescaling were carried out in the top heading. Air and water pipelines had to be pulled down before firing and thereafter laid again over the piles of broken rock which, naturally, was very time consuming and troublesome. The same applied to all transport of explosives, drill steels, etc., as well as personnel between the completed bottom of the tunnel to the bottom of the top heading.

Among the measures taken to reduce the above-mentioned difficulties can be mentioned:—

Principally for reasons of safety it was so arranged that the supply of electric power, mainly current for lighting purposes, to the operations conducted in the top heading took place via a cable run through a 4½ in. hole drilled from the ground surface approximately in the middle of the tunnel. Thus no cable passed the area where charging was taking place. Drilling and other operations in the top heading could be conducted irrespective of the charging.

Rapid coupling pipes for compressed air and water were replaced by hoses run over the piles of broken rock.

For the transport of personnel and material a trestle (nicknamed "Jacob's ladder"), transportable by tractor, provided with truck track and air winch, was designed (see Fig. 5). It can be mentioned that the upward transport of about 2 tons of dynamite and the downward transport of empty boxes, etc., took about 1 hour.

Drilling

Of the Sandvik 1¼ in. extension drill steels, two drill steels having a length of 4·8 m. and one drill steel of 2·4 m. were used for drilling to full hole depth. The threads, however, became worn out more quickly than the drill steels broke from fatigue, and to utilise the drill steels fully, the long steels were cut off to a length of 4·0 m. and threaded. It proved that drilling with 4·0 m. drill steels gave a better drilling rate and also less deviation from the theoretical position of the hole than drilling with 4·8 m. drill steels. This was probably due to the rod being subjected to less oscillation. There was reason for believing that the working life of the drill steel rod as well as the chain of the motor feed increased slightly. The chain hit less frequently against the drill-steel rod.

It will be seen from the drilling pattern, Fig. 2, that the interval between the run of holes in the wall is 2·2 m. = the distance between the row of holes. To make the tunnel wall as smooth as possible the jumbo was equipped at first with 10 rock drills, of which 8 drilled a run of holes across the width of the tunnel and one at each end of the jumbo was so arranged that holes were drilled halfway to the next run of holes. The interval between the holes was thus 1·1 m.

The abundance of fissures in the rock test carried out revealed that the tunnel walls did not become rougher if these extra holes were discarded. As this extra drilling was fairly troublesome these holes were discarded and subsequently 9 rock drills were employed for drilling the run of holes across the width of the tunnel.

Experience proved that a suitable hole depth under theoretical tunnel bottom was 1·2–1·6 m. Exceptionally, when the rock was particularly difficult to blast, holes to a depth of 2·0 m. were required. This drilling method resulted in a theoretical tunnel bottom being well blasted.

Predrilling through the roadway of the top heading and about 0·5 m. down into the rock was carried out with 64 mm. bits. In view of the risk of accidents occurring (drilling in missed holes when driving the top heading) remote distance operation of the rock drills was arranged and the workers were operating at a safe distance. From a safety point of view as well as for other reasons a distance of about 50 m. between the jumbo and the charging personnel was kept.

Charging and Firing

At first it was planned to fire 4 to 5 rows, about 9 m. bench, regularly every 24 hours. It was soon found, however, that the firing of considerably longer rounds gave a very much better operation result, and 9 to 12 row round lengths were used. The maximum was 13 rows, corresponding to about 3,700 cu. m. of broken rock. As each firing was accompanied by serious disturbances in the working rhythm (interruptions in air and water pipes and the connections in general between the completed tunnel bottom and the top heading) a doubling or trebling of the round lengths naturally implied a considerable improvement.

The firing sequence of the rounds was changed gradually in order to obtain the best shape and position of muck pile. At first the same interval was employed right across the bench and only the holes in the wall came one interval later. Gradually the drilling pattern shown in Fig. 2 was arrived at, which was characterised by a V-shaped arrangement of the interval series. Furthermore, the tip of the V was displaced to the left in the direction of the tunnel. The result was that the centre of gravity of the muck pile was pushed to the left and the rock size became smaller. Along the right-hand wall a lower heap of muck was formed which facilitated scaling and the running of

TABLE I.—MONTHLY ADVANCES WHEN BLASTING IN THE UPSTREAM SECTION OF THE TUNNEL

1956–1957	Monthly advances m.	Number of rounds	Metre per round	Number of calendar working days	m. per calendar working day	Remarks
May	76·6[1]	8	9·57	17	4·50	Running-in period
June	147·5[2]	16	9·22	24	6·15	
July	86·7	5	17·34	10	8·67	Vacations
August	233·0	12	19·41	27	8·63	
September ...	227·0	10	22·7	27	8·41	
October	221·0	10	22·1	27	8·19	
November ...	220·0	8	27·5	25	8·80	
December ...	163·0	9	18·1	18	9·10	Christmas vacation
January	234·0	12	19·3	26	9·00	
February ...	49·0[3]	3	16·3	18	2·70	Poor rock
Total and average	1,657·8	93	17·8	219	7·57	

(1) Work began on May 9.

(2) Agreement was reached with tunnel crew about piecework rate in middle of June

(3) Loading and haulage of the last rounds, as well as some broken rock left behind at the blasting in the downstream section, completed on February 20.

Fig. 7. A concrete-lined section of the top heading

pipelines as well as the mounting of lighting equipment. As a matter of fact all the pipelines were run along this wall. As the excavator used had the control cabin on the left the trucks were always loaded on the left side of the tunnel. Thanks to the displacement of the centre of the gravity of the muck pile a smaller swivelling angle for the excavator was obtained (see Fig. 2).

As the pipelines for compressed air and water were run along the right-hand wall, and as in certain cases the rounds had to be fired without taking the pipelines apart, detonation fuses were placed in the run of holes nearest the right-hand side (approximately 4 rows). When everything was ready for blasting and the pipelines pulled down, short-interval detonators were placed in the detonation fuses. This measure was taken to prevent detonation by means of vagabond currents or by the pipelines having become charged for one reason or another. For the same reason the conduits to the electric blasting caps were insulated before they were transported down to the working site.

The joining of the rounds in series was carried out at first at right angles to the direction of the tunnel, but after a missed round the joining was changed so that the series were joined parallel to the direction of the tunnel. It was hoped that a possible fault would not affect more than a part of the width of the round and that the greater part of the round would in any case shoot out. When a missed round occurred later the correctness of this assumption was confirmed. During the bench driving two missed rounds occurred owing to break-down in the electric cables.

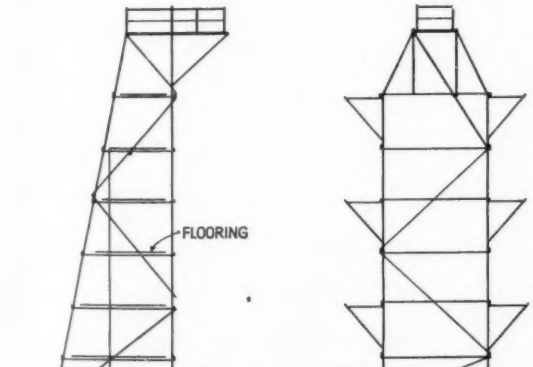


Fig. 8. Portable scaling trolley

Loading

As a rule the loading capacity was about 90% of that attained at the driving of the top heading, large lumps of rock being the main cause of the decrease. Generally each round was completely mucked out before the next round was fired. The reason for doing so was the desire to carry out possible after-blasting in the floor surface and in bench which had not been blasted. If this procedure is not adopted, experience in the Harrsele and other tunnels shows that the floor surface becomes higher and higher.

Scaling

Scaling had to be carried out in the top heading (prescaling), from the muck pile (scaling after each round) and the already blasted tunnel (after scaling). This operation became rather extensive and required not less than 0·115 hours per cu. m. or 18·5% of the

above-mentioned total working time per cu. metre of rock in the bench.

In the top heading scaling was carried out in front of the jumbo with the aid of a Hyster lift truck in combination with a platform erected on the fork.

After-scaling was carried out from a tubular structure of simple design mounted on wheels (see Fig. 8) and moved by means of a tractor.

Floor Surface Cleaning.

The uppermost 100 m. of the tunnel was minutely cleaned, but for the rest it was considered adequate to clean up the indents. In all about 23,000 cu. m. of rock and macadam from the road was mucked out. The thickness of the mucked layer was on the average hardly more than 0.5 m. The equipment used comprised three excavators type RB 19 provided with deep digging units and two tractors. Work commenced in the downstream section of the tunnel on May 2, 1957, and was completed on June 15, 1957. The broken rock was mucked out upstream.

Concrete Reinforcements

As mentioned, the permanent reinforcement operations were very extensive. In all not less than 26,000 cu. m. of concrete was placed. For the most part the placing was done by means of a concrete pump of the Blaw Knox type, which proved very satisfactory. A couple of flat-belt conveyors also proved very useful, particularly when lining the walls of the tunnel. In this connection large forms, transportable by means of cranes, were employed to a large extent. A couple of pictures, Figs. 1 and 7, will give an impression of the design and size of the reinforcement work.

Correspondence

Picote Station

To the Editor, WATER POWER

I have been interested to read the letter from Professor Gordon R. Williams drawing attention to the study of the Douro catchment carried out in 1951–53 by "Knappen-Tippetts-Abbett-McCarthy." Professor Williams is highly esteemed by those members of Hidro-Eléctrica do Douro who worked with him, but in order to avoid any possible misleading impression I think it will be wise to amplify some of his statements.

The Knappen-Tippetts-Abbett-McCarthy study was carried out under the auspices of the "Mutual Defense Assistance Program" and its great value, from the point of view of hydro-electric studies, lay in the emphasis it placed on the planning of a marginal type of power routing for prospective plants. The disclosure of any stretch of the Douro, or its tributaries, susceptible of hydro-electric development, other than those for which the Portuguese Hydraulic Department had placed proposals at the disposal of the consultants, did not result from this study, and was, indeed, excluded from it by contract. Actually, plans subsequently drawn up by the technical staff of Hidro-Eléctrica do Douro for the development of the Douro tributaries will raise their dependable output to 2,400 GWh per annum as against 400 GWh in the 1953 plan.

Professor Williams's reference to the "strong opposition" to the International Douro priority is, I feel, exaggerated, for according to my information the opposition came basically from a single, though eminent, engineer, and in fact, official approval to the priority of the International Douro development was by no means delayed.

The following extract from the formal proposals for the Picote plant presented to the Portuguese authorities in May 1955 is relevant:

"The scheme of the Portuguese International Douro hydro-electric development which, after comparison of several solutions, reveals itself as the most convenient, both technically and economically, includes three plants—Miranda, Picote and Bemposta—with corresponding gross heads of 56, 74 and 59 m.

"The present construction design concerns the second of these plants, which will be the first to be built. It embodies the results of multiple studies carried out since the establishment of Hidro-Eléctrica do Douro in July 1953, undertaken to secure the urgent construction of the Picote plant. These studies succeeded those initiated several years ago by 'Direcção Geral dos Serviços Hidráulicos' through the gathering of field data and later intensified by the elaboration of a study of the development of the Douro basin resources entrusted to the American consultant firm 'Knappen-Tippetts-Abbett-McCarthy'."

This quotation is here particularly due in order to remind that in that study the justification of the priority accorded to Picote among the developments of the Douro basin arose from a comparative analysis of the power potentialities, constructional practicability and costs of several solutions.

Between the previous proposals for Picote and those adopted for the actual construction there are basic differences which are the result of a revision carried out in the light of the experience gained in this country.

This revision was greatly assisted by the co-operation extended by Hidro-Eléctrica do Zêzere.

PAULO DE SERPA PINTO MARQUES,
President of the Administration,
Hidro-Eléctrica do Douro S.A.R.L.,
Oporto.

Aluminium Busbars. A publication entitled "Noral Rectangular Aluminium Busbar" has been issued by Northern Aluminium Co. Ltd., Banbury Oxfordshire. It is stated that an aluminium busbar costs only about half as much as its copper counterpart of equal current-carrying capacity, and is light, resistant to corrosion, readily welded, and not subject to progressive oxidation. The booklet contains data on the mechanical and electrical properties of electrical-purity aluminium (Noral C1SM) and the new conductor alloy (Noral D50SWP) that has been specially developed for electrical applications. Current ratings for a range of rectangular busbar sections are given, and recommendations on jointing methods are made. A new joint compound is described, and details of its current use are given. There is a short section on the bending of busbars, and on the correct types of bolts.

Book Reviews

Teorie Indirektni Regulace Rychlosti. By Prof. M. Nechleba. Published by SNTL (Státní nakladatelství technické literatury. Spálená 51, Prague 2. Cloth bound, 14 × 21 cm., 383 pp., 131 ff. Price 38 Kopecks.

Our review of "Water Turbines, Their Design and Equipment" in the February, 1959, issue mentioned Nechleba's book on "The Theory of Indirect Speed Control" which was published in 1944. A copy of the third edition recently released has been sent to us by the author. Although the text is in Czech a little patient mathematical study and some guidance from the English summary and chapter headings reveals its value. The English equivalents could have been usefully extended to the mathematical symbols since the notation occasionally deviates from that which is customary in Western Europe. A summary of the contents will illustrate the ground covered.

A description of the functions of indirect governor components, speed-responsive elements and damping devices in the control process leads up to five fundamental equations embracing the governor and regulated machine time constants. The effects of governor mass, insensitivity, time lag, valve lap, primary and secondary compensation, servomotor speed, regulating valve stroke, turbine and network self-regulation, pipeline pressure variations and upstream and downstream surge chambers are progressively introduced as the analysis becomes more comprehensive. The general solution defines the conditions which are necessary and sufficient for overall stability and culminates in a three-zone diagram showing stable, unstable and aperiodic regulation.

Vector representation with Nyquist and Leonhard amplitude and phase plane diagrams are freely used to demonstrate the interrelated action of the speed-responsive element with the pilot and regulating valves, their mass and overlap, which introduce unfavourable phase changes but which can be almost eliminated by proper design. It is also employed to determine the influence of waterhammer, closing times and turbine efficiency on the damping required.

An interesting chapter, based on Jost Hanny's "Reglungstheorie," is devoted to frequency characteristics, transient functions and frequency-response curves. Non-linear conditions, such as those associated with transient turbine-speed variations following load charges, are studied with Euler's step-by-step integration.

The close attention given to this problem in Eastern Europe is illustrated by a numerical example in Solodovnikov's "Transient Response from Frequency Response" which was translated into English, set on Varitype and published by "Infosearch," London. This deals with the overall turbine and governor performance as a distributed parameter system by the trapezoidal frequency-response method to derive transient response for which special tabulated functions are provided.

Turbine governing literature scattered through many foreign technical journals needs co-ordination to be of real engineering value. While a few specialised books such as Rich's "Hydraulic Transients," Gaden's "Considerations Sur Le Problème de la Stabilité" are helpful, and general works such as Leonhard's "Die Selbsttatige Regelung" and Hutarew's "Regelungstechnik" touch on water-turbine governing problems, a modern replacement for the specialised works of Tolle, Fabritz & Tenot, acknowledged in the bibliography, is badly wanted.

Nechleba's book, which is original and comprehensive in conception, fulfils this need in an absorbing application of the general theory of transient conditions in regulating mechanisms to water turbines and governors, and is, therefore, valuable to hydro-electric engineers whose tasks involve these problems.

The mathematical methods are restricted to simple differential equations, determinants, complex numbers and Laplace transforms which are coupled with excellent diagrams and typesetting. This suggests that translation should not only provide a useful and pleasant task for anyone with the linguistic and technical ability to undertake it, but also an admirable companion to Nechleba's "Water Turbines, Their Design and Equipment" which was put into English by H. G. Evans and Charles Mayer.

First Annual Symposium on Rock Mechanics. Golden, Colorado, U.S.A. Quarterly of the Colorado School of Mines. Vol. 51, No. 3, July 1956, 230 pp. Price 2 dollars U.S. Paper bound.

In a recent French textbook, J. Talobre rightly claimed that "Rock Mechanics" is a new science in its own right. On this same subject the American "Symposium on Rock Mechanics" is very different from Talobre's treatise. Talobre's approach was that of a hydro-electric engineer: Safety of tunnels, strength of rock, overburden conditions and imperviousness of rock were the main subjects of his treatise. The approach of the American team of specialists is typical of mining engineers.

The book opens with a contribution by W. Livingstone on "Rock Failure" which is correlated to the transfer of energy. The author describes the "strain energy range" when energy is transmitted to the solid by vibration. As the weight of explosive detonated at a given depth below the surface of the earth in a given type of material is increased, the surface above the charge begins to fail. The depth at which failure begins is the "critical depth" N and the weight w_c of explosives used is the critical weight: $N = E^3\sqrt{w_c}$ (E = strain energy factor). Similar fundamental relations are developed for the "shock range" and the "fragmentation range."

Parts I and IV of the Symposium are on rock failure and rock fragmentation by blasting. Obert, Noren and Kumao Hino report on test results on rock blasting. F. W. Brown writes on basic performance properties of blasting explosives. The theory of fracture is dealt with by H. Odel. He considers elliptical cracks existing near a vertical borehole and calculates the maximum stresses caused at the edge of the elliptical crack. Finally, he establishes the direction of the crack to find the most dangerous stress conditions.

Part II deals with the design and support of underground openings. D. Banister reports on the strata research programme of the School of Mines, Durham, England. This programme can be subdivided into the following sections: The photoelastic analysis of stress around mining excavations; the measurement of rock pressures below ground by mechanical methods or sonic location methods; the determination of loads on underground supports; strain measurements in strata;

mechanical properties of coal and allied rock. Stress redistribution on the periphery of openings is dealt with by J. J. Reed, who describes models and laboratory tests. Poollen's contribution is on similar lines.

Part III, on mining by block caving (by Bucky and Hannifour), also gives much useful information.

Abbreviations of Associations, Institutions, Research and Trade Associations. The British Electrical and Allied Manufacturers' Association, 36 Kingsway, London, W.C.2. Single copies 1s. 6d.; 20 for £1; 100 for £4; all post free.

So many are the abbreviations in common use to denote associations, institutions, political organisations and government departments that the hapless engineer nowadays has to acquaint himself with a new and fearsome kind of alphabet. He will be greatly assisted in this task by this booklet which BEAMA has produced, primarily for the convenience of its members but also for the use of any other interested organisations or individuals. The booklet is a revised and enlarged edition of the original publication in 1957, and contains the recognised abbreviations of those organisations—British, overseas, and international—most likely to be met by those in the electrical and allied industries.

Talsperren (Dams). By Dr. Heinrich Press. Vol. I. Second edition. Published by Wilhelm Ernst & Sohn, Berlin-Wilmersdorf, Hohenzollerndamm 169. 1958. 671 ff. Price DM. 50 (paper cover); DM. 54 (bound).

Shortly after the war (1953–54) Prof. H. Press, Berlin Institute of Technology, published a treatise on water-power structures in three volumes. Volume I is on dams. The general comment on these three volumes when they first appeared was that they gave an up-to-date and precise description of modern hydro-power structures and designs. The author was able to draw ample information from German sources and also from France, Italy, Switzerland, and from the U.S.A. In addition, he incorporated in his treatise much of his and his assistants' own research work.

It is most promising that an entirely revised second edition of Volume I is now available. For comparison, the 1953 first edition comprised 212 pages, whereas the second edition contains 395 pages (practically double). Most of the additional pages have been used for illustrations and diagrams; there are only a few basic changes in the text.

The book now includes descriptions of the most recent structures, such as the Zervreila arch dam (Switzerland), the Bin-el-Ouidane arch dam (Morocco), the Roselend dam (Electricité de France), which is a bold combination of an arch dam design with a buttress-type superstructure. Among modern buttress dams, the new edition describes the Ben Metir dam (Algeria), by Stucky, and the most recent Italian buttress dams by Marcello (Italy).

An important addition is the chapter in which the heightening of dams is discussed. In its new form, the treatise is very much up to date, and its value is enhanced by about 600 figures and diagrams.

It can be recommended to all engineers dealing with dams and hydro-power structures.

The main chapters are: General Remarks; Dams—the acting forces, classification; Gravity Dams; Arch-Gravity Dams; Arch Dams; Cupola Dams (shells); Buttress Dams; Heightening of Existing Dams; Subterranean Dams; Contractors' Plant; Flood Discharge; Supervision of Dams; Earth and Rockfill Dams.

An extensive bibliography and a good index are to be found at the end of the treatise.

The Technical Writer. By J. W. Godfrey and G. Parr, M.I.E.E. Published by Chapman & Hall Limited, 37 Essex Street, London, W.C.2. 340 pp. 110 ff. Price 45 shillings net.

The whole question of technical journalism and authorship has been discussed in this excellent book. Although it may seem strange for comment on this subject to appear in WATER POWER, a few minutes' thought will show that clear objective expression is a fundamental necessity in any technical publication, however specialised, and that muddled prose can only confuse and exasperate the reader. Since the ability to read and write is the basis of all education, the art of clear expression in technical subjects is too often underestimated, with the result that the unwary may fail to treat vocabulary and grammar with the respect to which they are entitled.

The would-be author should read this book carefully; it will help him to develop a good, clear style, and will save him from some of the more common grammatical pitfalls. Chapters dealing with the mechanics of printing, and the whole process of production, explain the intricacies of the publishing business, thus enabling the reader to assess the problems that have to be overcome. An appendix giving printers' and authors' proof-correction marks will also be invaluable to those who have not already learned these symbols.

Tunnel Engineering. By Rolt Hammond, A.C.G.I., A.M.I.C.E. Published by Heywood and Company Ltd., Carlton House, Great Queen Street, London, W.C.2. 332 pp., 113 ff. Price 55s.

This book is a review of tunnel engineering practice and much of the information it contains has been obtained from the published writings of such authorities as Fox, Jaeger, Glossop, Collet and so on. The subjects covered include lining methods, shield and subaqueous tunnelling, and surveys. An interesting chapter is devoted to a brief history of tunnelling; the description of some methods used by the Roman engineers may well make their present-day counterparts shudder in sympathy. A section of particular value to hydro-electric engineers is the description of tunnel linings at the Allt-na-Lairige, Quoich and Breadalbane schemes in Scotland.

Although this book does not claim to be anything but a survey of tunnelling methods and practice, it will be found a useful work of reference for general information on the subject, particularly for non-specialist engineers and students.

Dominion Tilting Disc Check Valves. The Dominion Engineering Company Limited have issued a brochure describing the technical features of the Dominion Tilting Disc Check Valve which they manufacture. This type of valve is generally suitable for use with any centrifugal pump or blower and will operate satisfactorily on either the discharge or intake side. The brochure gives a brief history of the development of the tilting disc check valve and provides specifications of the various sizes of valve available.

Joy-Sullivan Air-Power Division

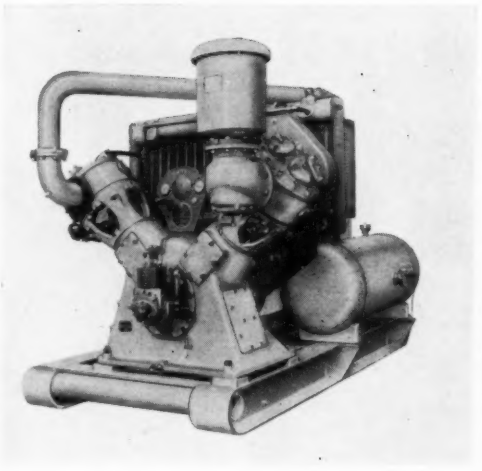


Fig. 1. WN102 semi-portable compressor; Fig. 2. Airvane portable compressor

JOY-SULLIVAN LIMITED, which has registered offices at 7 Harley Street, London, W.1, and main works in Greenock, and is a wholly owned subsidiary of the Joy Manufacturing Company of Pittsburgh, Pennsylvania, has set up an Air-Power Division to manufacture for the world market a range of air compressors and pneumatic tools for civil-engineering, tunnelling, mining, road-construction and similar work. The establishment of this Division represents the culmination of three years' organisation and development, during which time a careful selection was made of parent-company's designs which had proved themselves in practice and appeared to be the most suitable for the market in view. Subsequently the appropriate manufacturing facilities had to be planned and set up at Greenock, and all the lines adopted are now in process of manufacture.

In the field of air compressors, a stationary, a semi-portable, and a portable range are available, each in a series of capacities. The stationary compressor, the WN112, is a two-stage V-type reciprocating machine built in four sizes offering a choice of capacities from 400 to 850 cu. ft. per min. at 125 lb. per sq. in., and is normally driven by a flange-mounted motor. Truncated aluminium pistons and alloy-iron crossheads have been adopted, running in renewable alloy-iron liners. The main bearings are of the spherical roller type, and the crankpin bearings are of the steel-backed precision type. Separate forced-feed lubrication systems are applied to the cylinders and valves and to the running gear. The valves are of the "dual-cushion" type; each spring plate has a number of evenly spaced waves and the reaction plate has twice as many waves as the spring plate. Cylinder heads and intercooler

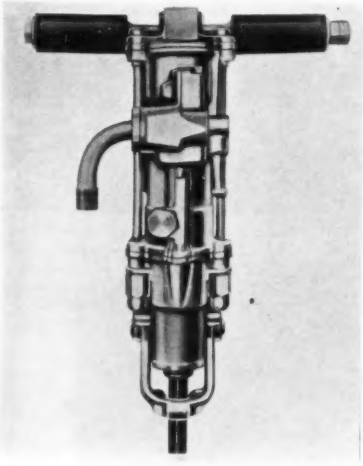


Fig. 3. L37 drill

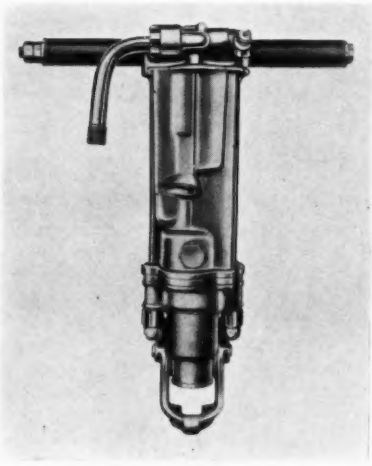


Fig. 4. L47 drill

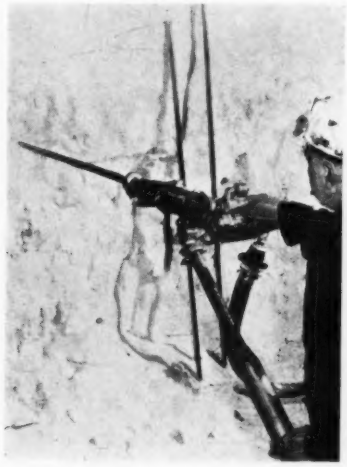


Fig. 5. JAL47 drill

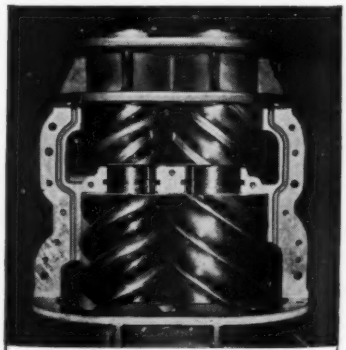
The world's first PORTABLE rotary screw compressor

TWIN-AIR breaks new ground for the jet age

At Arlanda, where Stockholm's new airport for jet traffic is being built, a Twin-Air has been used to produce power for some of the most difficult drilling jobs in hard rock.

The Twin-Air is a new Atlas Copco compressor designed for building and construction work, quarrying, and all projects where there is a demand for larger portable units. This new portable has been developed from the successful Twin-Air stationary compressors, which have now been operating for more than two years in mines and industrial plants. Based on an original Swedish invention, the Twin-Air is completely different from conventional rotary compressors. It has no wearing parts in the two oil-flooded compression chambers, because there is no metallic contact. As a result, maintenance and overhauls are kept to a minimum.

The rotary screw design guarantees a smooth air-flow, free from surging characteristics, and in addition the Twin-Air has the overall operating efficiency which only a two-stage machine can give.



The main components of the Twin-Air are two screws which intermesh without metallic contact.

The first models in this new range are the 370 c.f.m. and 620 c.f.m. machines. Both are 100% air-cooled, diesel-powered units.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent, or write to
Atlas Copco AB, Stockholm 1, Sweden, or Atlas Copco (Great Britain) Ltd., Maylands Avenue, Hemel Hempstead, Herts.

P31

are cooled by water circulation. A standard Joy unloader regulates the air supply to the receiver.

For construction work a skid-mounted semi-portable variant of this machine is available. It is listed as the WN102 and is depicted in Fig. 1.

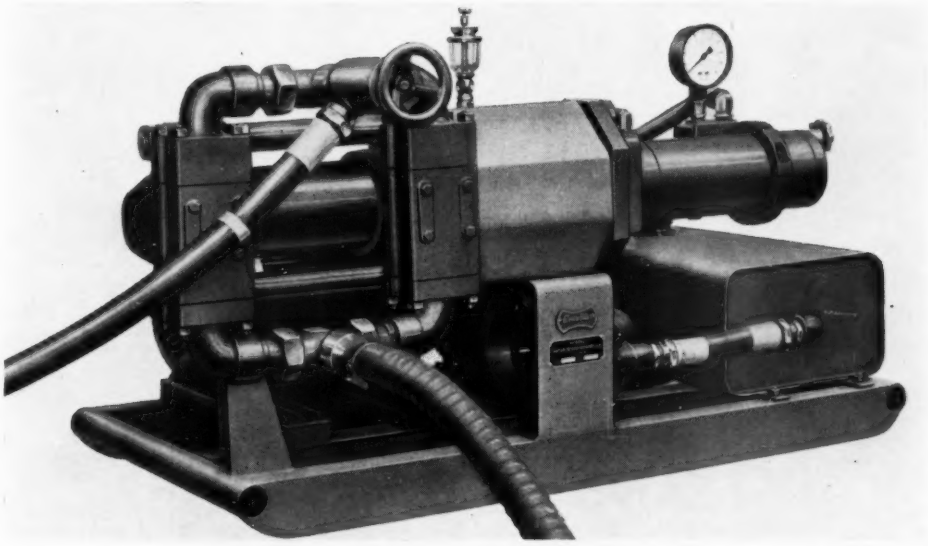
The portable compressor, seen in Fig. 2, is of the rotary-vane type and is available in two sizes—the RP365 and the RP600, rated respectively at 365 and 600 cu. ft. per min. at 100 lb. per sq. in. A built-in safety circuit shuts off the engine in the event of high engine-water temperature, low engine-oil pressure or high compressor-discharge temperature; this circuit is normally closed so that it fails to safety in the event of an electrical fault. Another feature is a thermal bypass which supplies warm oil to the compressor and subsequently maintains it at the correct operating temperature regardless of outside conditions. Thus, it is claimed, the compressor can be operated in sub-zero temperatures. A proportional load control regulates the engine speed to suit the air demand.

Three rock drills are manufactured. These are depicted in Figs. 3–5 and include the L37 35 lb. drill, the L47 50 lb. hand-held model, and the JAL47 50 lb. airleg machine. All these drills—known as the "Speedline" range—have a dual-valve feature which affords independent positive air control on the up and down piston strokes. The use of cadmium plating permits finer tolerances between piston and cylinder wall, prevents scoring during the run-in period and prevents rusting when standing idle. All models can be supplied for either wet or dry drilling. The L37 weighs 37 lb. dry and 39 lb. wet and is 17 in. long. The standard chuck size is $\frac{7}{8}$ in. hexagon and $4\frac{1}{4}$ in. long. The series 47 models weigh 50 lb. dry and 52 lb. wet and are 22 in. long. The standard chuck size is $\frac{7}{8}$ in. hexagon by $4\frac{1}{4}$ in. with an alternative of 1 in. hexagon. The airleg weighs 32 lb. and has a feed length of 48 in. The L37 drill can drill depths up to 8 ft. in average conditions, and the hand-held L47 up to 10 ft., or up to 14 ft. in favourable conditions.

Two paving breakers are also available—a 65 lb. and an 80 lb. machine.

The foregoing new products from the British company will supplement existing products available to users of air-power equipment, including single-drum and double-drum hoists, double-drum slushers, lightweight and medium-weight wagon drills, shovel loaders and scraper loaders.

Craelius Grouting Equipment



Craelius high-pressure grouting pump

Grouting is being used more and more in civil engineering practice and is invaluable in dam-foundation work and strengthening rock in water tunnels. After 30 years of experience the Craelius Company of London, W.1, now supply a variety of pressure grouting equipment that is at once light, compact, transportable, and is easy to operate. The ZH-50 pump will handle a variety of grout mixtures at pressures up to 1,000 lb. per sq. in. with a 110 mm. standard liner or up to 1,700 lb. per sq. in. with an 80 mm. liner, both liners being interchangeable. This pump is illustrated herewith. It is double acting and can be driven by either electricity or compressed air. Double action is secured by a spring-loaded switch-over mechanism which ensures minimum pressure fluctuations when the movement of the piston is reversed at the end of each stroke. An important feature is the pressure control which is fully adjustable between zero and maximum and is totally independent of the quantity of grout being handled. The liners and piston rods are chrome plated and honed to reduce friction and resist corrosive action. Ball valves of hardened

A RECORD START!

FOR THE NEW

Atlas Copco Bencher

USING

Sandvik Coromant Steels

750 feet drilled by one man in a single shift, using two Atlas Copco Benchers fitted with Lion rock drills and Sandvik Coromant drill steels! The outstanding possibilities of this new drilling combination are shown by performances like this put up recently at drilling sites in Sweden.

The Atlas Copco Bencher comprises a rock drill mounted on a vertical pusher feed. It is ideal for service in rough terrain where wagon drills cannot conveniently be used, or for small-scale benching projects where wagon drills are uneconomical. Benching is faster and cheaper than with hand held machines. Heavier, higher capacity rock drills can be used and one man can easily operate two Benchers at the same time.

SANDVIK COROMANT STEELS

Sandvik Coromant are today's most widely used drill steels currently drilling more than 1300 million feet of rock a year.

Their quality is high and uniform—guaranteeing a low cost per foot at all times.

A complete range of compressed air equipment

Atlas Copco manufacture portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. These are sold and serviced by companies or agents in ninety countries throughout the world.

One man can easily operate two Benchers simultaneously.

To secure the rig, bolt holes are drilled and anchor bolts and wedges placed in and driven tight. The bencher is placed on the heads of the anchor bolts and the feed is locked at the desired angle with chained wedges.
The operator can easily drill additional bolt holes while the rock drills already set up are running.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent or Atlas Copco (Great Britain) Limited, Maylands Avenue, Hemel Hempstead, Herts. or write to Atlas Copco AB, Stockholm 1, Sweden

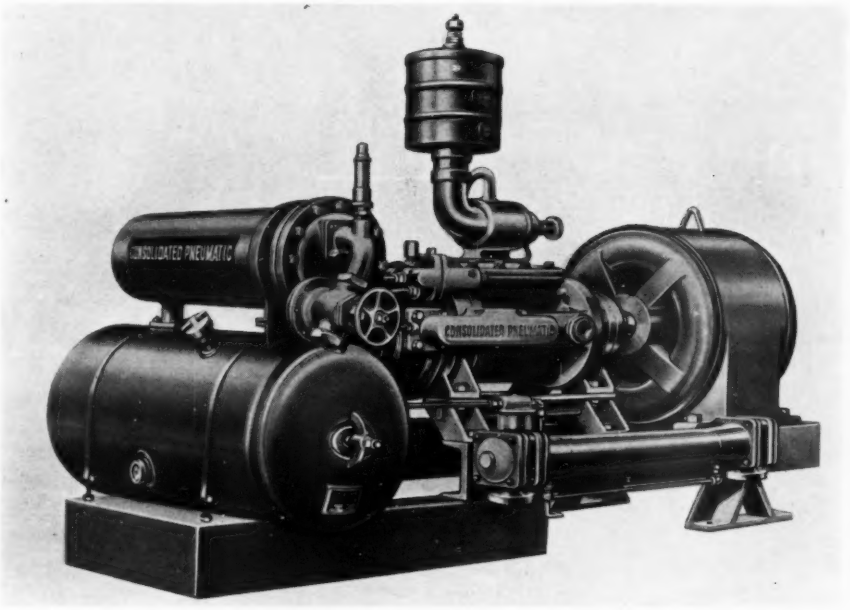
DSS105

steel are provided, and both the balls and their seats are easily replaceable.

For the maximum pressure of 1,700 lb. per sq. in. and with the supplementary 80 mm. liner, the capacity is 5·7 gallons per min. and 10 h.p. is required. With a similar power requirement and the use of the 110 mm. liner the pump will deliver 11 gallons per min. at a pressure of 1,000 lb. per sq. in. A 5 h.p. unit is also provided covering the whole range of pressures from 500 to 1,700 lb. per sq. in. With this the quantities of pulp injected range between 11 gallons per min. at 500 lb. per sq. in. to 3·1 gallons per min. at 1,700 lb. per sq. in.

Auxiliary equipment consists of the ZM-300 high-speed mixer and the ZA-600 grout agitator. To seal off the hole when it is being grouted several designs of packer are available. These depend virtually on putting rubber seals under axial compression; if multi-stage grouting is required a deep-hole packer is run to the required depth on light extension tubes and then raised to the required level for each subsequent grouting operation.

New Range of C.P. Compressors



C.P. Class R stationary portable compressor

A development of their range of oil-cooled rotary "Power Vane" compressors is announced by the Consolidated Pneumatic Tool Company Limited, of 232, Dawes Road, London, S.W.6, with the introduction of the Class R range for stationary electric operation, together with optional water cooling of the oil as an alternative to air cooling. The new range consists of units with capacities of 100, 135. 160, 300 and 510 cu. ft. per min. at a pressure of 100 lb. per sq. in.

The compressor consists of a simple vane-type rotor enclosed in a sealed compression casing. The rotary principle results in smooth operation and pulsation-free air delivery. Inlet and discharge porting eliminates valves, and two-stage compression develops top performance without excess loading of parts.

The oil is circulated by the pressure differential between the receiver and compressor and is metered by a gear-type pump. Cooling of the oil is effected either in a fan-cooled radiator or, where it is necessary to avoid undue raising of the surrounding air temperature and adequate water supplies exist, by a water-cooled unit.

Specific features include a gradual unloading control to regulate compressor output, Vokes Micro-Vee type filters with cleaning device and squirrel-cage screen-protected motors with star-delta starters for wall mounting. Further features include the use of Norgen automatic drain valves and a hand-operated starting valve. To build up when starting and to bleed off this pressure when closing down, an automatic service discharge valve is installed.

Demag British Agency. William H. Capper & Co. Ltd., Mayfair House, 8/9, Hertford Street, London, W.1, Tel. Grosvenor 2341, have been appointed Agents in the United Kingdom and Northern Ireland for Demag, Duisburg, Western Germany. The equipment handled under this new arrangement includes mining equipment and compressors of all types for all capacities and pressures. Demag-trained engineers are resident at the above address for advice and enquiries. William H. Capper & Co. Ltd. will undertake installation and service and are equipped to design, fabricate and install associated pipework.

The only crawler-mounted loader with SWIVELLING ACTION

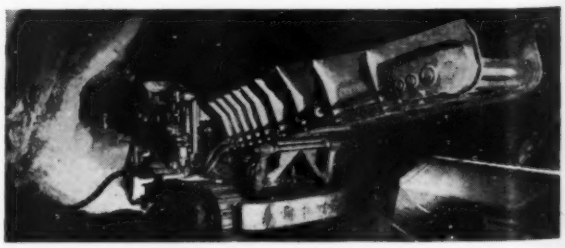
The new LM500 air-powered loader is the result of four years' development work under hard operating conditions. Designed for use in tunnels, mining drifts and general underground excavations where trackless transports are advantageous, the LM500 is the only crawler-mounted loader with swivelling action.

Output is high! The bucket capacity is 650 litres, the movement swift and *the throw can be made without centring*. The swivelling action allows a width of up to three metres (9′ 10″) to be cleared without turning the crawler bands.

A conveyor permits continuous discharge even when the loader is moving back and forth. Discharge height can be varied between 1,140 and 1,950 mm. (45·3″ and 76·8″) so that most types of dumpers can be used. Another advantage is that heavy boulders can be lowered gently into dumpers and transport cars. In fact discharge is so smooth that ordinary motor lorries can be used.

An efficient 28 h.p. traction motor and sturdy crawler tracks make the LM500 a powerful machine able to advance easily into any rock pile. Being air-powered the loader emits no diesel exhaust fumes—vitally important underground.

Maximum bucket height	**2,700 mm. (106·3″)**
Free discharge height	**1,150·6-1,950·7 mm. (45·3-76·8″)**
Free conveyor length	**2,530-2,700 mm. (99·6-106·3″)**



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Abstracts from the World Technical Press

Investigating Pressure Surges in Penstocks

The author gives an account of his investigation, by means of an electric analog, of the pressure surges produced in penstocks by a periodic disturbance at their downstream end. He first describes the analog used which reproduces the characteristics of a hydro plant comprising a conduit with a single characteristic fed by a constant-level reservoir. The measurements were taken by means of a two-way cathodic oscillograph. The periodic disturbance which causes the pressure surges under investigation is merely the slight reduction of the penstock discharge caused by the blades of the runner of the turbine when passing in front of the openings of the guide vane. The results obtained are in close agreement with those of Bergeron's graphical method, and establish the efficiency of the electric analog designed by the author. (J. Piquemal, *Mémoires et Travaux de la Société Hydrotechnique de France*, Vol. 1958, No. II, p. 153, and *La Houille Blanche*, Vol. 13, No. B, December 1958, p. 767; 8 pp., 6 ff.)

Helio-Electric Power Plants

This paper examines the main technical and economic criteria involved in harnessing of solar energy to the industrial production of electric power. The favourable characteristics of incorporating helio-electric plants into hydro-electric power generating systems are stressed, and an attempt is made to forecast the cost of energy produced in Italy in helio-electric plants the construction of which is considered technically possible today. Appended to the article are suggestions for an improved terminology of the technology of solar energy, as well as an extensive bibliography. (Dr. Ing. Giorgio Bugliarello, *L'Energia Elettrica*, Vol. XLV, No. 12, December 1958, p. 1179, 16 pp., 14 ff.)

Uruguay

The bulk of the electric energy available in Uruguay is produced and distributed by "Administración General de las Usinas Eléctricas y Los Telefonos del Estado" (U.T.E.). In 1957 U.T.E.'s production amounted to 1,155 million kWh, the contribution of water power, restricted to the Rincon del Bonete-Montevideo system, being 550·4 million kWh. Installed hydro-electric capacity, no more than 32,000 kW in 1932, increased to 128,000 kW in 1950 and was still at the same level in 1957. The 102,600 kW Rincon de Baygorria plant, on which work started recently, will substantially improve the development of the Rio Negro with an average yearly production of 450 million kWh. Topographical and geological surveys are now in progress for another Rio Negro hydro-electric plant to be built downstream from Baygorria in the region of Paso del Puerto, and projects for a third plant, still farther downstream, in the vicinity of Yapeyu, as well as for a new thermal plant near Montevideo, are in course of elaboration. Transmission lines do not exceed 2,000 km. in aggregate length, and operate at 110 or 30 kV, with the exception of the Rincon Bonete-Montevideo 150 kV line to which the new hydro-electric plants will also be connected. (*Quaderni di Studi e Notizie*, Vol. 15, No. 282, January 1, 1959, pp. 26–8, 1 map, 3 tables.)

NOTE. Electrification in Uruguay is also the object of an article in *Wasser- und Energiewirtschaft*, Vol. 51, No. 1–2, January–February 1959, p. 29, 8 pp., 9 ff.)

Applying Kaplan Turbines to Waste Discharge

The Palaminy plant, now in course of construction on the middle stretch of the Garonne, comprises a diversion canal about 7 km. long, leading to a forebay formed along an embankment at the toe of which stands the power house. The two Kaplan turbines of the plant are each connected with the forebay by means of a 5 m. diameter penstock and their discharge is returned to the river through a tailrace 0·5 km. in length. The maximum gross head is 28·9 m., and the rated net head at the maximum discharge of 135 cu. m. per sec. is 26·4 m. In order to damp surge waves resulting in the headrace from a sudden closure of the turbine, and to save the cost of a spillway or any other work or equipment ensuring the evacuation of the surplus discharge, provision has been made for throwing out of adjustment the blades of the runner in relation to the guide vanes of each turbine, so as to maintain the waste flow at about 50% of the rated discharge. This mode of operating the turbine so to speak as waste-discharge control has been the object of tests on reduced-scale models by the manufacturers. To became industrially workable, it requires an injection of air above the runner so as to shift the zone of energy dissipation to the space under the runner. This process is not exactly a novelty, but at Palaminy it calls for the introduction of some special arrangements, among others a "closure-limiting device" which prevents the flow from being interrupted completely, even for very short periods. Another very simple device causes the turbine to act automatically as waste discharge at whatever speed closure operates and as soon as it passes the half-open position. A short account of the discussion which followed the reading of this paper is appended. (R. Monteil & J. Abbo, *Mémoires & Travaux de la Société Hydrotechnique de France*, Vol. 1958, No. II, p. 145, and *La Houille Blanche*, Vol. 13, No. B, p. 759; 8 pp., 6 ff.)

Tower Cranes in Dam Building

This paper reviews different types of tower cranes ranging from heavy monolithic structures of 100 tons capacity to lightweight self-erecting cranes, with passing references to climbing cranes and mobile tower cranes. The use of these machines in industry is discussed, and it is beyond question that they have effected considerable savings in building multi-storey and other high concrete structures. Reference is made of the use of mono-tower cranes on the Roxburgh dam. A modern mono-tower crane consists of a fixed or travelling tower which supports a vertical rotating mast, the lower section of which is located within the tower; the mast rests on a large footstep bearing, and is held laterally by a set of cast-steel rollers on the top of the tower. A luffing jib is attached to one side of

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the mast, and on the opposite side is fixed a counter-weight. Hoisting, luffing and slewing are effected by separate motors housed in the rear compartment of the control cabin fitted to the mast above the tower. The crane can be propelled by mounting it on powered bogies. It is obvious that the application of mono-tower cranes to dam building depends above all on the topography of the construction site. (Robert J. Shannon, *N.Z. Engineering*, Vol. 14, No. 1, January 1959, p. 2, 9 pp., 14 ff.)

Overflow Works in Small Streams

Though restricted to small structures, this study is of general interest since it deals more particularly with stilling pools from the aspect of energy dissipation and erosion prevention. The author proceeds from Sperlich's empirical formulae for free and submerged overfalls, drawn from the tests he carried out on small-scale models of natural stilling pools with a view to determining approximately in advance the shape and size of built-in stilling pools in connection with two-dimensional flow. The complication of sediment transport was also taken into account. Stilling pools with three-dimensional flow can be obtained by widening the channel at the top so as to have, instead of vertical walls, banks sloping at a correct angle. This pattern brings about the formation of rollers in the vicinity of the banks, which enable the stilling pool to be 10 to 20% shorter than with two-dimensional flow. (Karl Fanta, *Die Wasserwirtschaft*, Vol. 49, No. 1, January 1959, p. 14, 8 pp., 12 ff.)

Building a Concrete Dam by Spraying

The multiple-arch dam instanced, 62 ft. high and 436 ft. long, which is to provide the water supply of the village of Equeurdeville, near Cherbourg, was built by an uncommon procedure. Upon completion of the ribs or buttresses between each two of the fourteen 28 ft. span arches of the dam, the contractor attached to the ribs wooden skids which enabled the 10 ft. long archforms to be pulled upward as concreting progressed. Four sets of forms were used, each set remaining in position four days. The concrete spraying equipment supplied by Compagnie Parisienne d'Outillage à Air Comprimé, consisted of a 6 ft. conical mix container which forced the concrete through a hose to the nozzle; then, from a second hose, another supply of compressed air splattered the concrete against the forms of the structure. The 8 in. thickness of the arches, which slope 1 : 1, was built up in two sprayed layers, the first 6 in., the second 2 in. thick. The arch reinforcement consisted of two layers of $\frac{5}{16}$ in. rods running from top to bottom and two layers of $\frac{7}{16}$ in. rods placed diagonally at 45°. The first 26 ft. of the bottom section of the arches were concreted from ground level, and the remaining 78 ft. 6 in. of the length of arches, by moving the concreting equipment to a footbridge set along the top of the dam. One man did the spraying from a platform, which was hoisted by a winch up the inclined arches each time the forms were raised; two other men on the platform tamped and trowelled the fresh concrete. The mix used contained equal amounts of sand (0–$\frac{5}{16}$ in.) and crushed stone ($\frac{3}{16}$ to $\frac{9}{16}$ in.) (*Engineering News-Record*, Vol. 162, No. 3, January 22, 1959, p. 37, 1 f.)

Underground Hydro-Electric Power Stations

This paper discusses the reasons for the increasing popularity of underground hydro-electric power stations. The historical development of underground plant is reviewed, and the article includes references to both thermal and nuclear installations.

In about 1889, what may have been the world's first underground hydro-electric power development was installed in one of the mines of the Comstock Lode at Virginia City, Nevada. This plant comprised six 40 in. impulse wheels operating under a vertical head of 1,680 ft., each runner being connected to a generator supplying power to the mill a short distance away. Designs and techniques have gradually improved during the past 50 years and there are now almost 300 underground hydro-electric power stations either in service or under construction, the total installed capacity of which will be some 31,000,000 kW. Many more such projects are in the planning stage and when these come into operation, there will be another 30,000,000 kW of installed capacity.

Underground plants have been widely built in Norway, Sweden, Switzerland, France, Italy and Yugoslavia. They have been constructed in at least 29 countries and this number will soon be increased. There are 60 underground power stations in service in Italy, with 8 under construction; Sweden has 26 in service, with a total capacity of 2,700,000 kW, another 18 stations being under construction.

In places where underground hydro-electric plants can be adapted to satisfy geological and economic requirements, neither geography nor climate affect their use. Such power stations have been built in the far north, well above the Arctic Circle, examples being the Porjus and Harsprånget developments in Sweden and the Niva development in Russia. They have also been built in warmer climates, such as Algeria, Brazil, Peru and El Salvador.

Every hydro-electric project must be specially designed and there is no general rule which can be applied to determine whether a particular site is more suitable for development as a surface power station or as an underground plant; various alternative possibilities must be carefully evaluated before the most economic solution can be found.

After discussing the economics of underground power stations, and some of the considerations which must be taken into account when comparing the relative advantages and disadvantages of underground and surface plant, the author considers the geological aspects and the question of design. A further interesting section is devoted to failures in underground penstocks and conduits; there have been cases in the past of failure along fissures in the rock, resulting in local concentrations of pressure and high resultant bending stresses in the liner.

The most notable failures were those at Gerlos, Austria, in 1945 and 1948. The steel-lined underground penstock serving the conventional Gerlos power station was placed in service in August 1945. On October 30 of that year two failures along the penstock caused extensive damage. After repair work was completed, another similar but less severe accident occurred. The power station recommenced operating in March 1948 but another failure took place in September of the same year. Further repairs were

then carried out and since restarting in December 1948, it is believed that there has been no further trouble. The Gerlos penstock is about 4,170 ft. long and is inclined at an angle of some 27 degrees to the horizontal. The internal diameter decreases from 7·22 ft. at the upper end to 5·25 ft. at the lower. Thickness of the liner varies from 0·472 in. to 1·20 in. and tensile strength of the steel is about 58,300 to 68,300 p.s.i. The penstock was designed to withstand full hydrostatic pressure without reaching the yield point of the steel.

The penstock was driven through quartz phyllite and shale rocks, with frequent transition from compact to badly fractured schistose or argillaceous zones. The light to dark grey phyllite is interrelated with thin bands of limestone and Dolomite. All the failures involved ruptures along lines parallel to the inspection and drainage gallery of 2·65 ft. width, located under the penstock and separated from it by a thin concrete masonry member; large quantities of rock were eroded at each failure and the generating gear was flooded.

When the reasons for these failures were investigated, it was found that one cause might have been the fracture of the concrete sheath surrounding the liner although much of the evidence pointed to brittle fracture of the steel. (F. L. Lawton, M.E.I.C., Chief Engineer, Power Department, Aluminium Laboratories Limited, *The Engineering Journal*, Vol. 42, No. 1, January 1959, p. 33, 18 pp., 20 ff.)

Rhine Development

After Germany's objections to the completion of the Rhine lateral canal as planned by France, both countries agreed on October 27, 1956, to a solution providing for a new pattern of development between Breisach and Strasburg. This reduces the 118 km. in length of the original lateral canal to 65 km., and the aggregate head from 109 to 50 m. Four stages are contemplated, their length and head remaining as planned for the full-length canal. The main dam of each stage, erected across the river half-way between the power stages, has five 30 m. openings controlled by double hook gates. The head of the four stages varies between 8 and 11 m. At the Markolsheim stage, the spillway can discharge through four openings 5,600 cu. m. per sec., while maintaining the pool level prescribed; a further discharge of 1,200 cu. m. per sec. is ensured by the spillway of the power house, and if the discharge capacity of the turbines running idle, of the ice pass, and of the filling and emptying sluices of the navigation locks are added to this total of 6,800 cu. m. per sec., there is a very substantial margin of safety against the highest flood discharge of the Rhine, which is assessed at 5,500 cu. m. per sec. The canal dykes have a maximum height of 12 m., the bank slope being 1 : 2 on the land side and 1 : 2·5 on the Rhine side. At the upstream end of each stage the river bed is to be deepened 2 m. The tailrace canal and the power house differ in pattern from the stages already completed only by the higher installed discharge, which is to be increased from 1,080 to 1,400 cu. m. per sec. This has been brought about by the amended plans, in which the wet cross-section of the new stretches will have to be increased from 900 to 1,200 sq. m. The layout of the power houses proper remains unchanged. There will be four generating sets to each plant, with four emergency spillways controlled by tainter gates between No. 2 and No. 3 turbines. Pending the completion of the nearest downstream stage, the head at all stages will be 13 to 15 m., to be reduced to 12 m. by the backwater of the completed downstream stage. While the new solution involves an increase in capital expenditure through the building of the main dam across the river itself, the high connecting dykes, the higher installed discharge, and the deepening of the bed at the upper end of each stage, it is expected that the energy output will be higher. Also, the agreed plan enables the power plants to utilise higher discharges at low water level, the additional energy produced being throughout firm power, the value of which is assessed at twice as much as non-firm power. (Helmut Seifert, *Die Wasserwirtschaft*, Vol. 49, No. 2, February 1959, p. 29, 5 pp., 3 ff.)

Influence of Earthquakes on Dams

The authors of this paper emphasise how important it is, when working out projects to be erected in regions subject to seismic shocks, to take into account the hazards connected with such occurrences. It is obvious that calculation must include the additional horizontal and vertical stresses acting on the dam body itself and the water stored. Hypotheses generally advanced prove that studies and research on the subject are still at their initial stage of development. This article, in two instalments, summarises the work carried out in this connection on behalf of the Yugoslav Electricity Authority. The first part deals with general notions on earthquakes and their classification, defines the regions of Yugoslavia more particularly affected by shocks, and examines the mechanism of their effect. The second part discusses the actual effect of the stresses caused by seismic movements on the various types of structures: gravity, arched, and fill dams. The influence of earthquakes on the ground is then examined, a distinction being made between sound and hard rocky formations, which transmit tremors with uniform intensity, and non-cohesive soils, in which shocks are considerably more dangerous. Following a brief account of the observations made on structures actually perturbed by earthquakes, the authors draw general conclusions among which the importance of deep foundations is particularly stressed, since the quality of the rock increases with depth, and the effect of the tremors decreases. (B. Kouyoundjitch and D. Milovanovich, *Construction*, Vol. XIII; No. 8, August 1958, p. 225; No. 9, September 1958, p. 257; 11 pp., 8 ff.).

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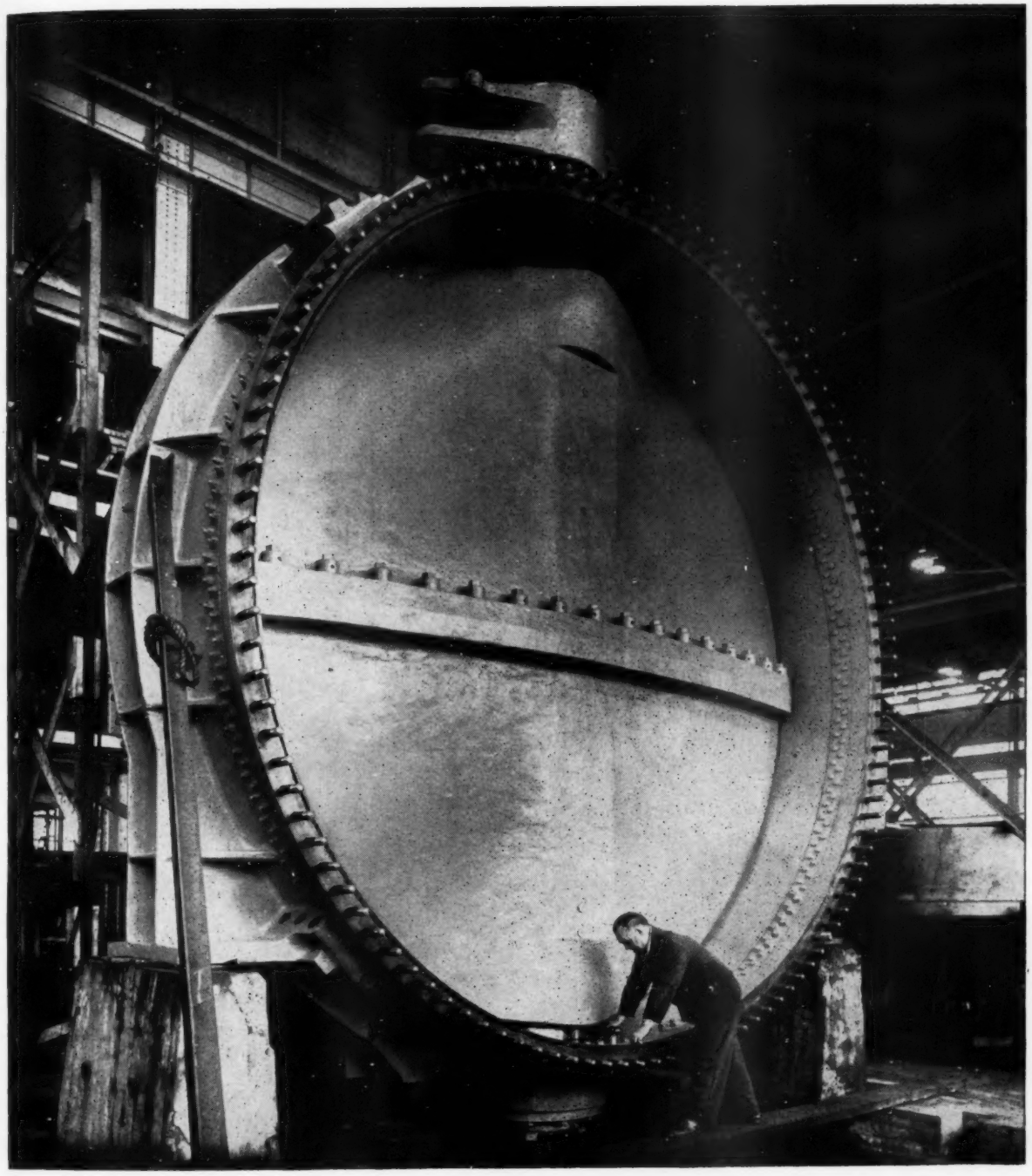

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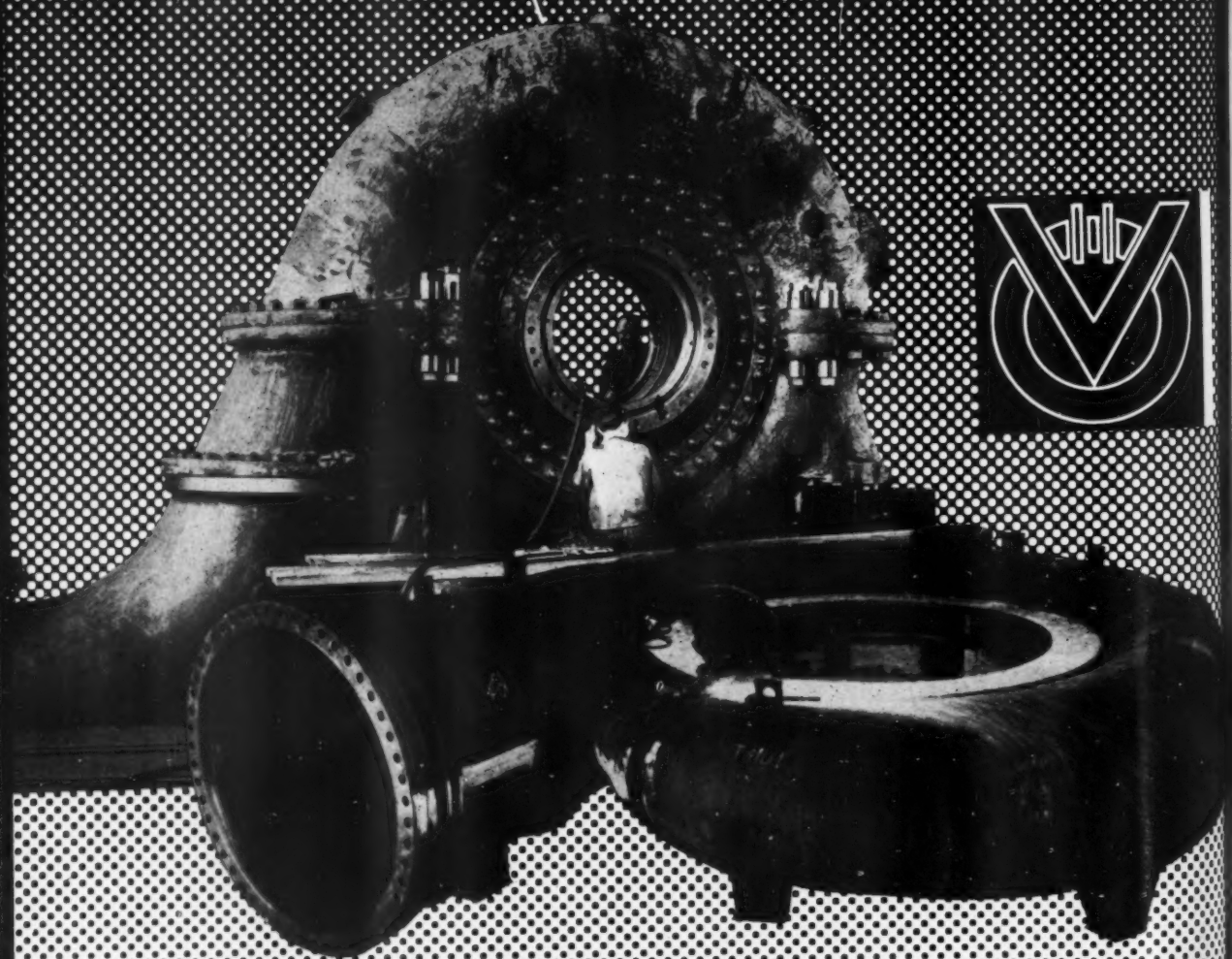

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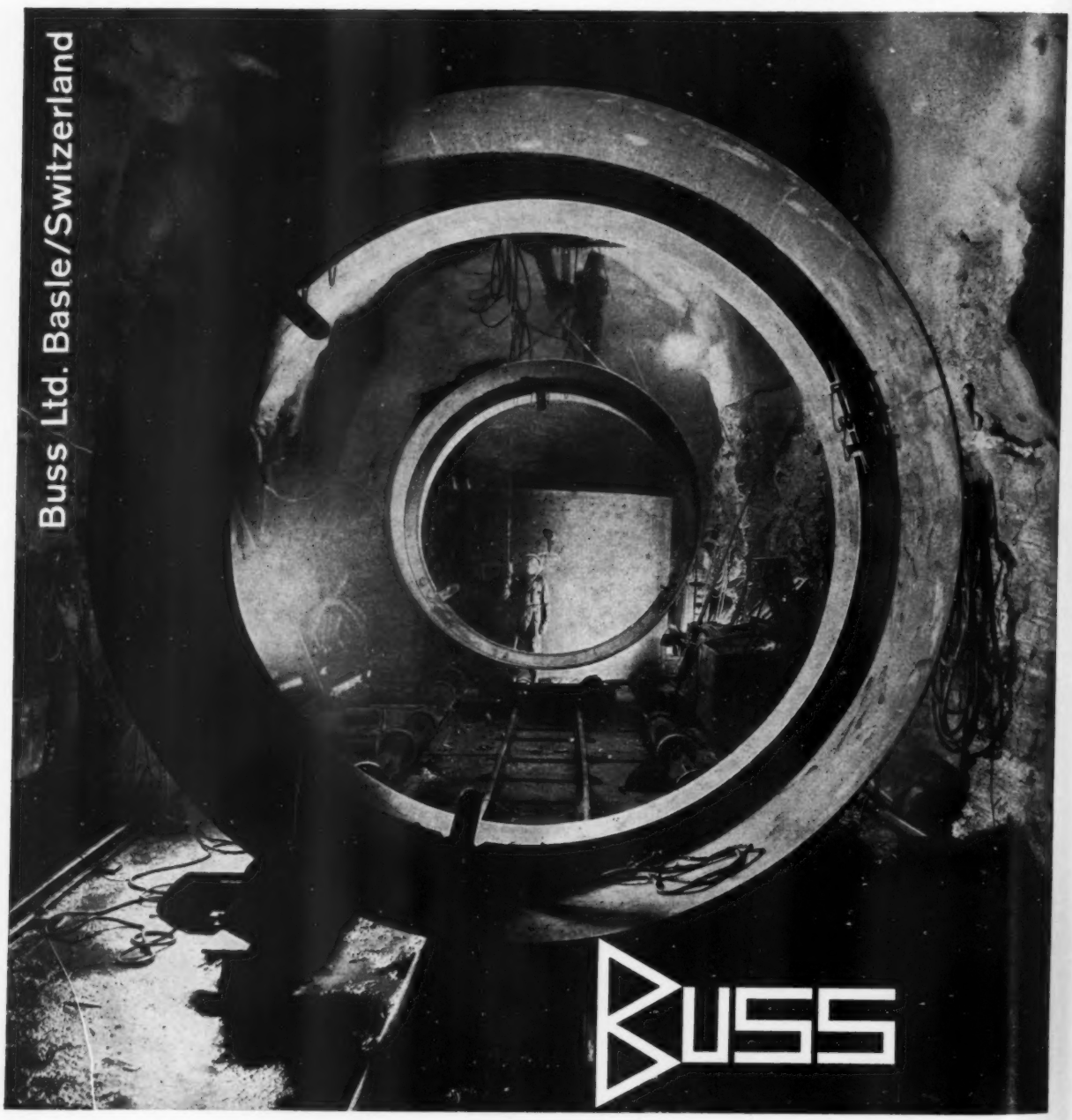

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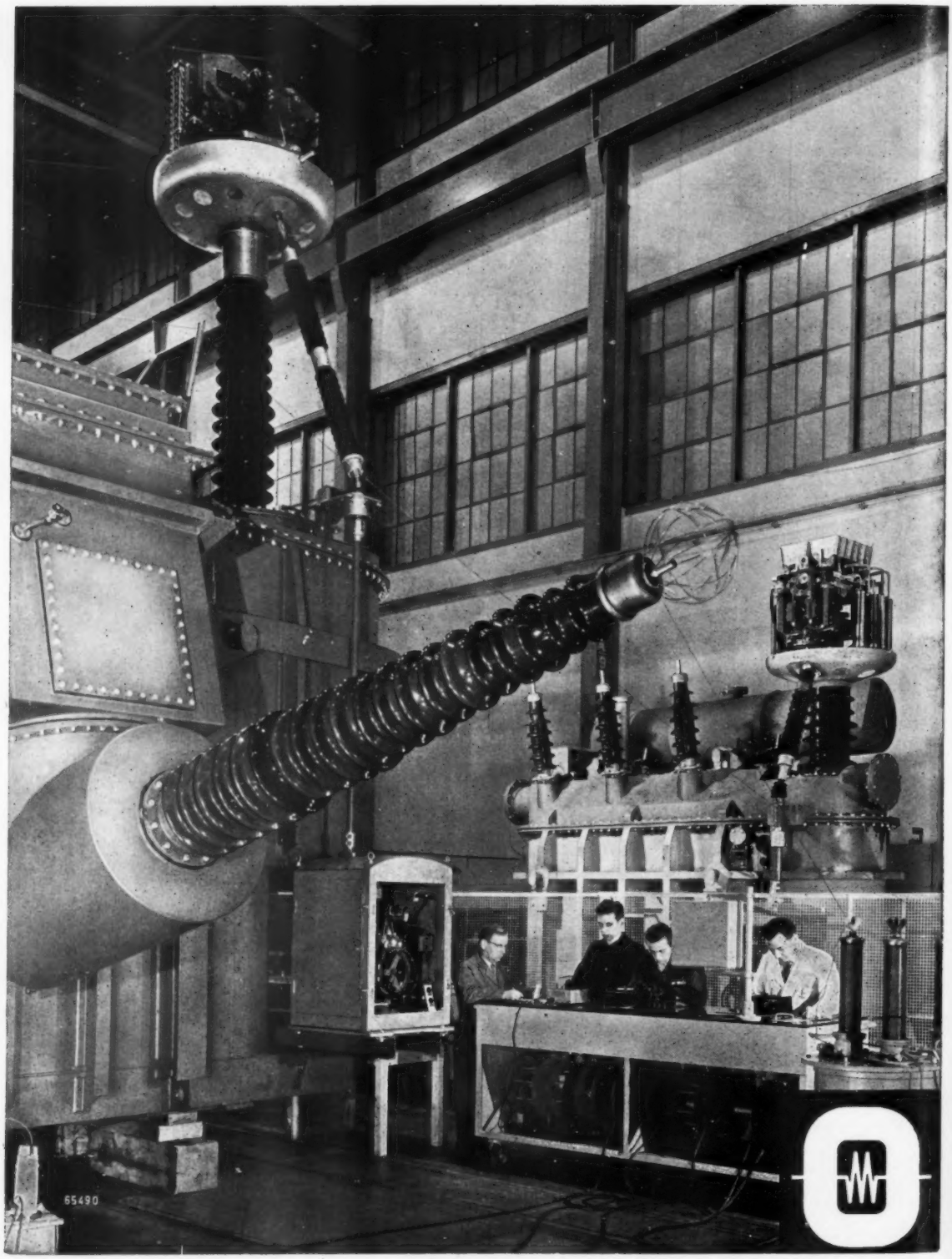

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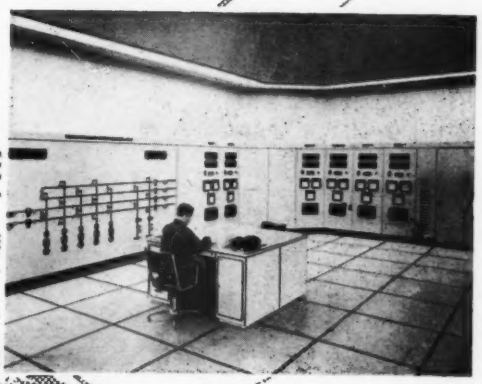

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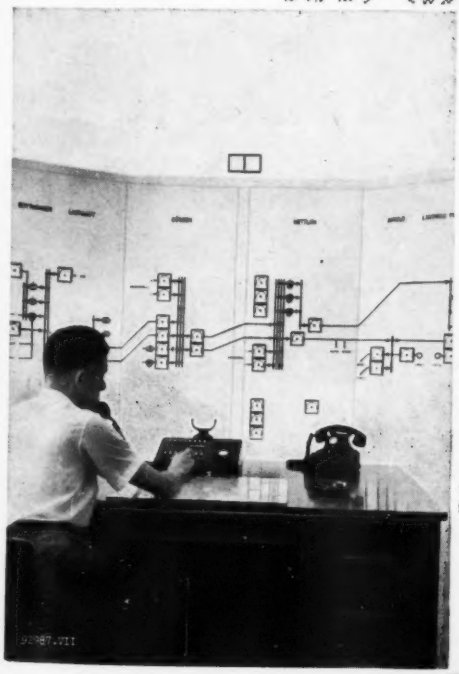

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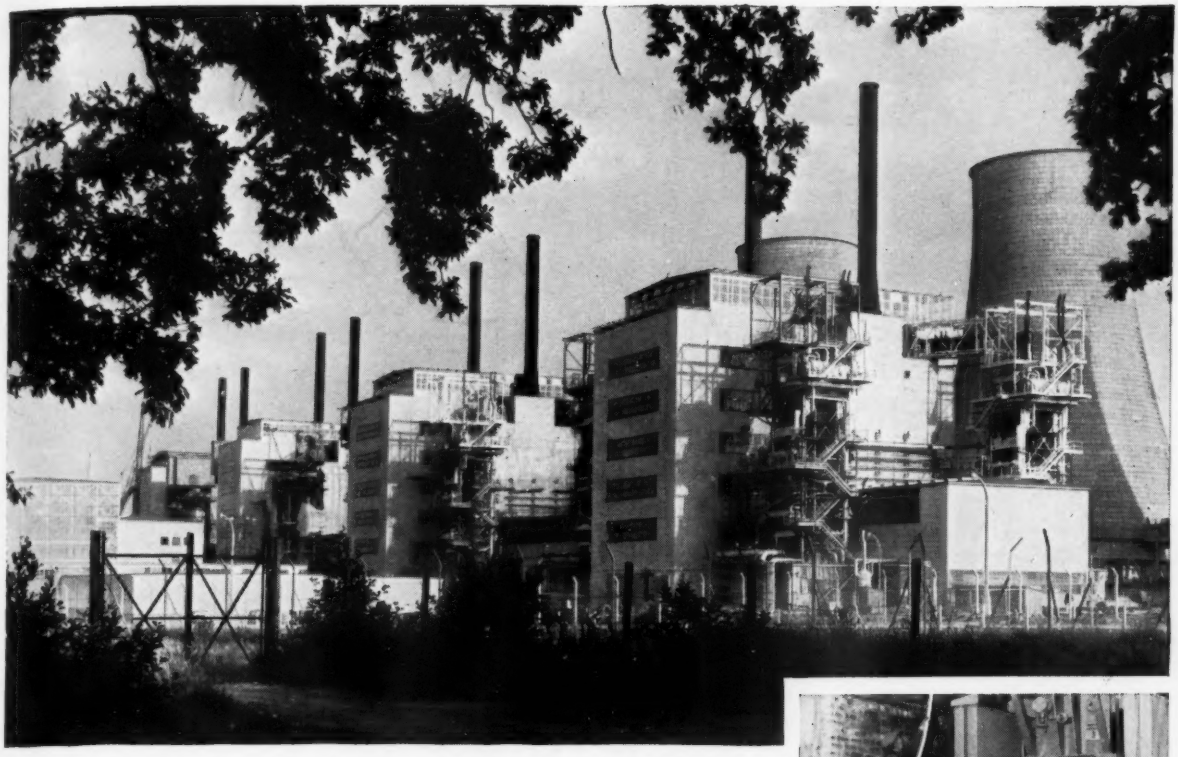

RIGHT: *Installing Henley single-core 33 kV cables in Turbine Hall Transformer Bays.*
BELOW: *Henley Control Cables rising to Reactor No.1 Control Panels.*

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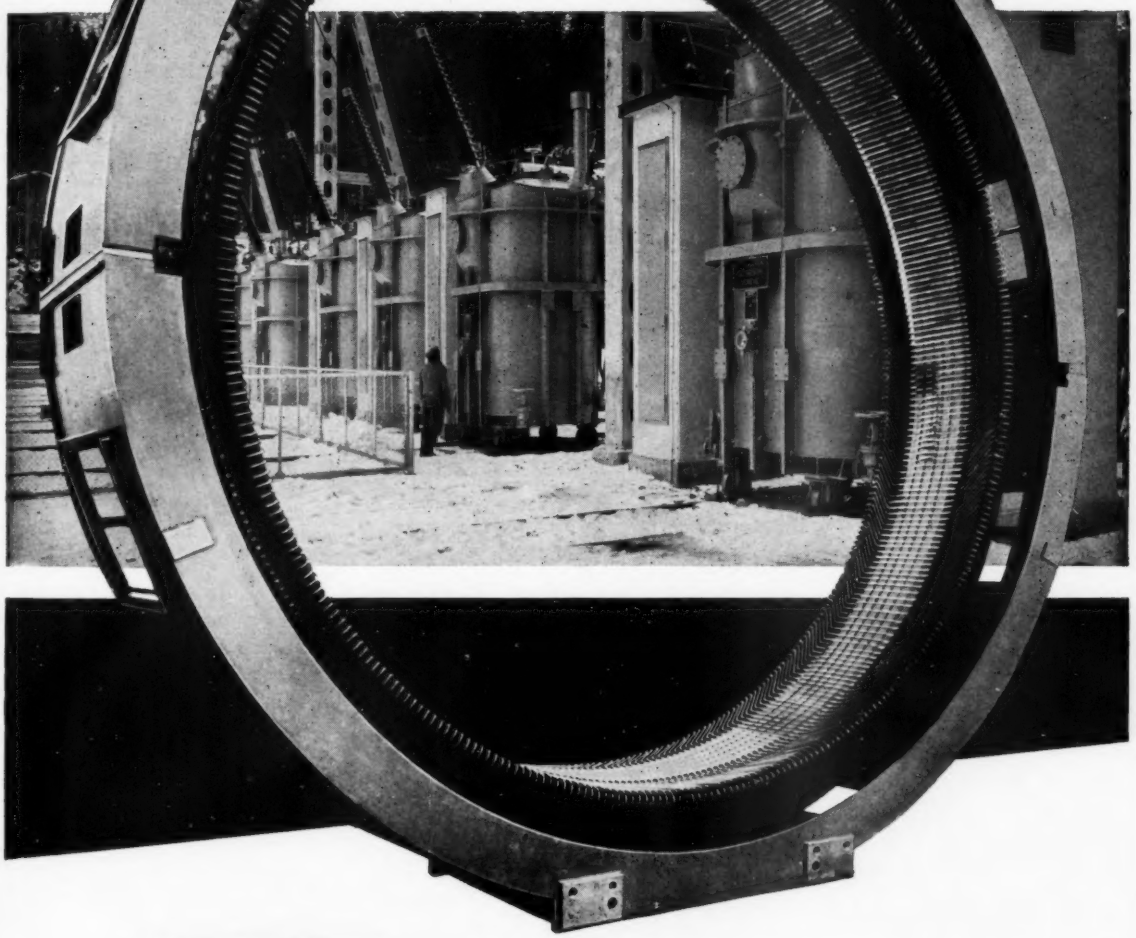

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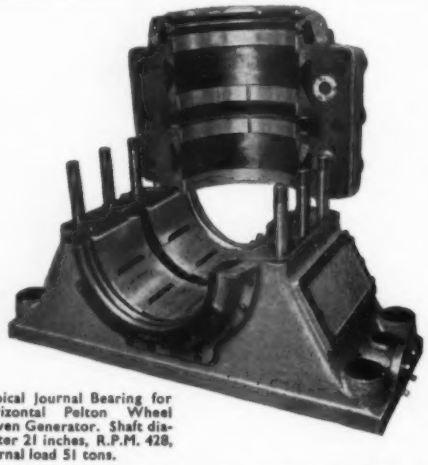

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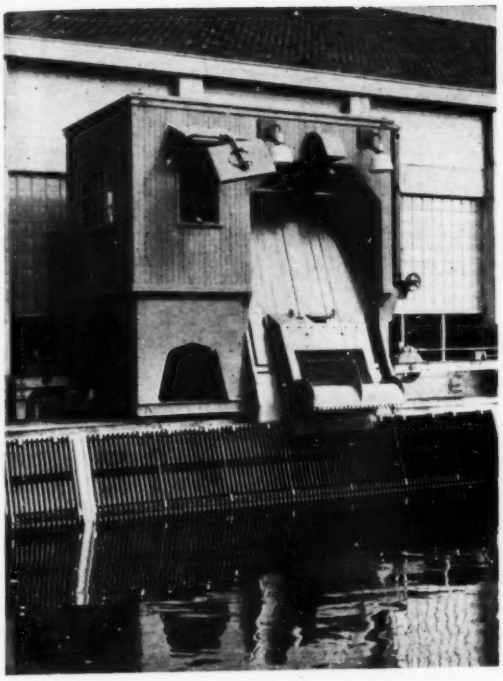

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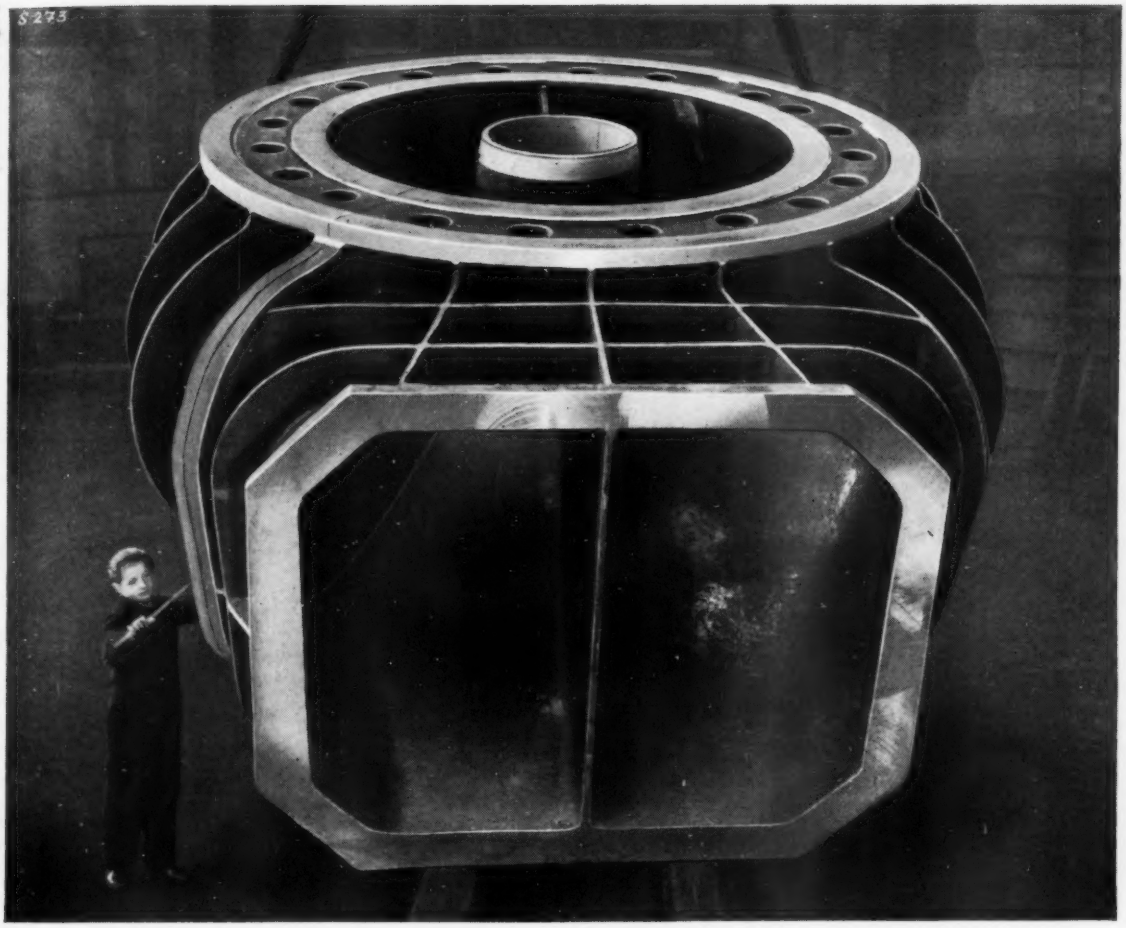

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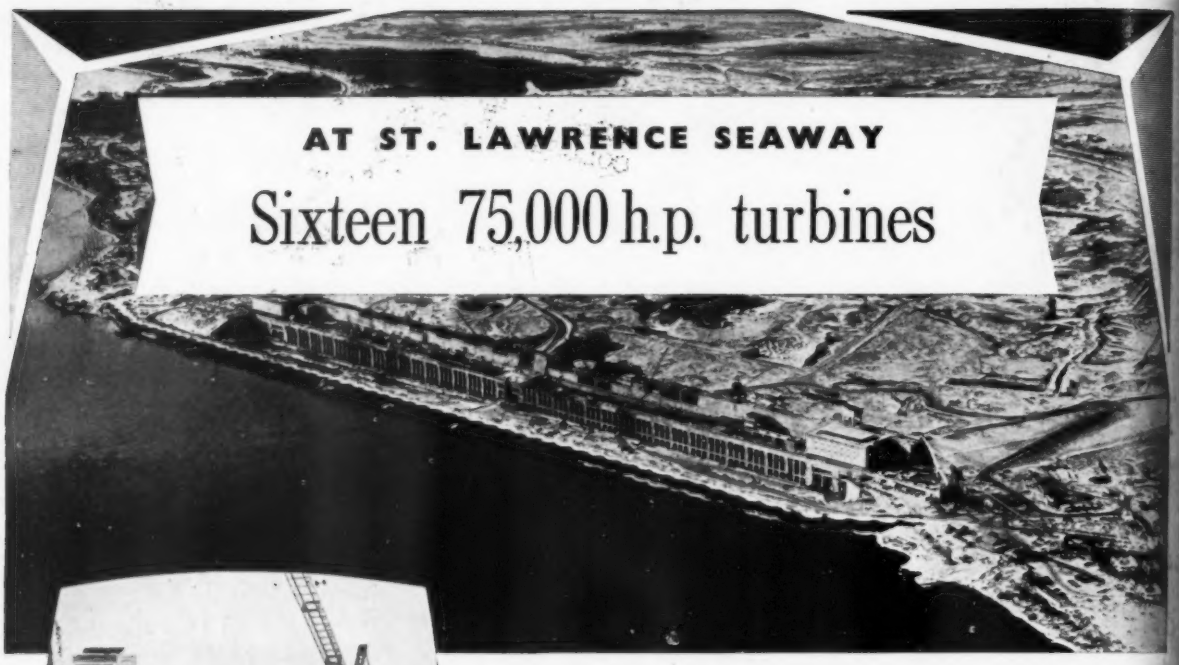

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